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ON THE COVER: Ms. Wendy J. Sheppard, Agricultural Technician, and Gary A. Theil, Nursery Superintendent, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center, inspect nursery crops in winter storage house.

Photo by Thomas A. Fretz

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Characterization of the Winter Buds of Crabapple Species with the Scanning Electron Microscope

JULIA MARTENS and THOMAS A. FRETZ[1]

INTRODUCTION

Morphological similarity is quite often a problem in the positive identification of plant varieties. This is particularly true when plants are not in flower or are in the leafless winter condition. Correct identification is necessary for consistent cultivar propagation, effective breeding programs, and cultivar disease resistance studies.

Previous research has demonstrated that the scanning electron microscope (SEM) is an invaluable tool in morphological studies (1, 4, 8). Entire three-dimensional structures can be directly observed instead of reconstructed from a slide series. In recent years the SEM has become more widely used in research pertaining to flower bud initiation, insect host preference (3), and characterization of taxonomical groups (7). Several researchers have made use of the SEM to differentiate between species (2, 7) and between clones (5). The majority of SEM morphological work has dealt with either herbaceous plant material or crops of economic importance rather than woody ornamentals. One notable exception is Krause's work (5) with American elms, where he was able to establish identifying features of the leaves belonging to two similar clones.

The objective of this study was to examine the winter buds of a chosen group of crabapple species for characteristic morphological structures that would differentiate each species from the others. For initial work, five species of upright, green-leaved, and red-fruited crabapples were selected.

MATERIALS AND METHODS

The crabapple species chosen were *Malus baccata* var. *mandshurica, M.* 'Red Jade', *M. robusta, M. sargentii,* and *M. zumi* 'Calocarpa'. All crabapple buds were taken from single mature trees growing in the Secrest Arboretum at the OARDC, Wooster, during March 1977. The twig specimens were clipped from outside branches at random intervals around each tree.

Immediately after clipping, the terminal buds were removed from the twigs, sliced in half longitudinally, and placed in 5% glutaraldehyde (in a pH 7.2 phosphate buffer) for 3½ hours at room temperature. The buds were then dehydrated in 10, 25, 50, 75, 95%, and absolute ethanol (one-half hour each), placed in amyl acetate, and ultimately critical-point dried (CPD) with liquid CO_2. Specimens were attached to stubs with graphite cement and coated with carbon and gold in a vacuum evaporator.

Three to five samples of each of the five species have been examined thus far on a Hitachi S-500 scanning electron microscope. All specimens were examined at 10 to 20 kv and photomicrographs were obtained using Polaroid type 55 P/N film. All photomicrographs were oriented parallel to the longitudinal axis of the buds.

RESULTS AND DISCUSSION

Among the morphological features occurring consistently were several that were distinctive from species to species, and a few that were useful as identifying characteristics. Although trichome structure has been helpful elsewhere for identification purposes (4), such was not the case for crabapple buds. The shape and size of trichomes varied from point to point on a given bud, and no subsidiary cell arrangements were observable at the point of attachment to the bud surface.

The form and structure of cuticular wax has been found to be consistent in some evergreens (6) but proved to be variable on the crabapple species examined to date. In general, scales lowest on a given bud carried a heavier wax layer than scales nearer the bud tip. The structures that proved most distinctive between species were bud scale stomates and the overall 'cell pattern' of the scales. The topography, shape, and orientation of the cells of the scale surface, or cell pattern, were very useful as corollary observations.

Given this groundwork, differences between the five crabapple species could be readily pointed out. None of the buds of *M.* 'Red Jade' examined showed discernible stomates. By this characteristic alone it was unique, since the other four species exhibited unmistakable stomates (Fig. 2). The cell pattern of *M.* 'Red Jade' was fairly regular and flat (Fig. 1A), with cells arranged in short semi-parallel lines. On this species the overlaying wax appeared fairly thin and only small, scattered wax aggregates were observed.

M. zumi 'Calocarpa' buds also had only a thin wax layer, but in this species the stomates were numerous and very distinctive (Fig. 2A). The whole stomatal unit appeared as a noticeable clump of cells and was composed of five to seven subsidiary cells arranged concentrically around a stomatal opening or a simple depression. In many groupings the bowed shape of

[1]Graduate Research Associate and Associate Professor, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

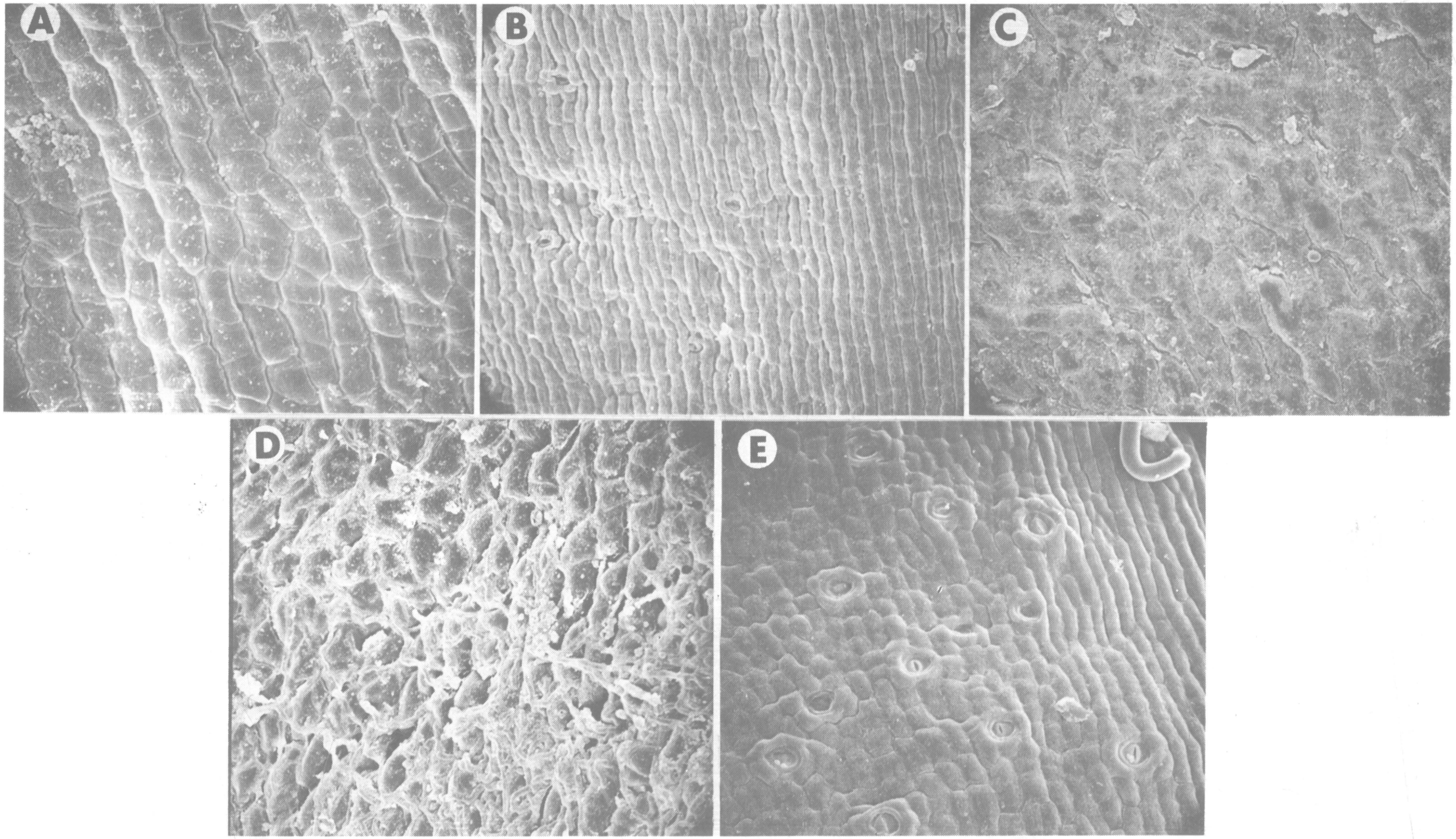

FIG. 1.—Bud cell patterns of Malus species. (A) M. 'Red Jade' x 500; (B) M. zumi 'Calocarpa' x 200; (C) M. sargentii x 500; (D) M. robusta x 600; (E) M. baccata var. mandshurica x 400.

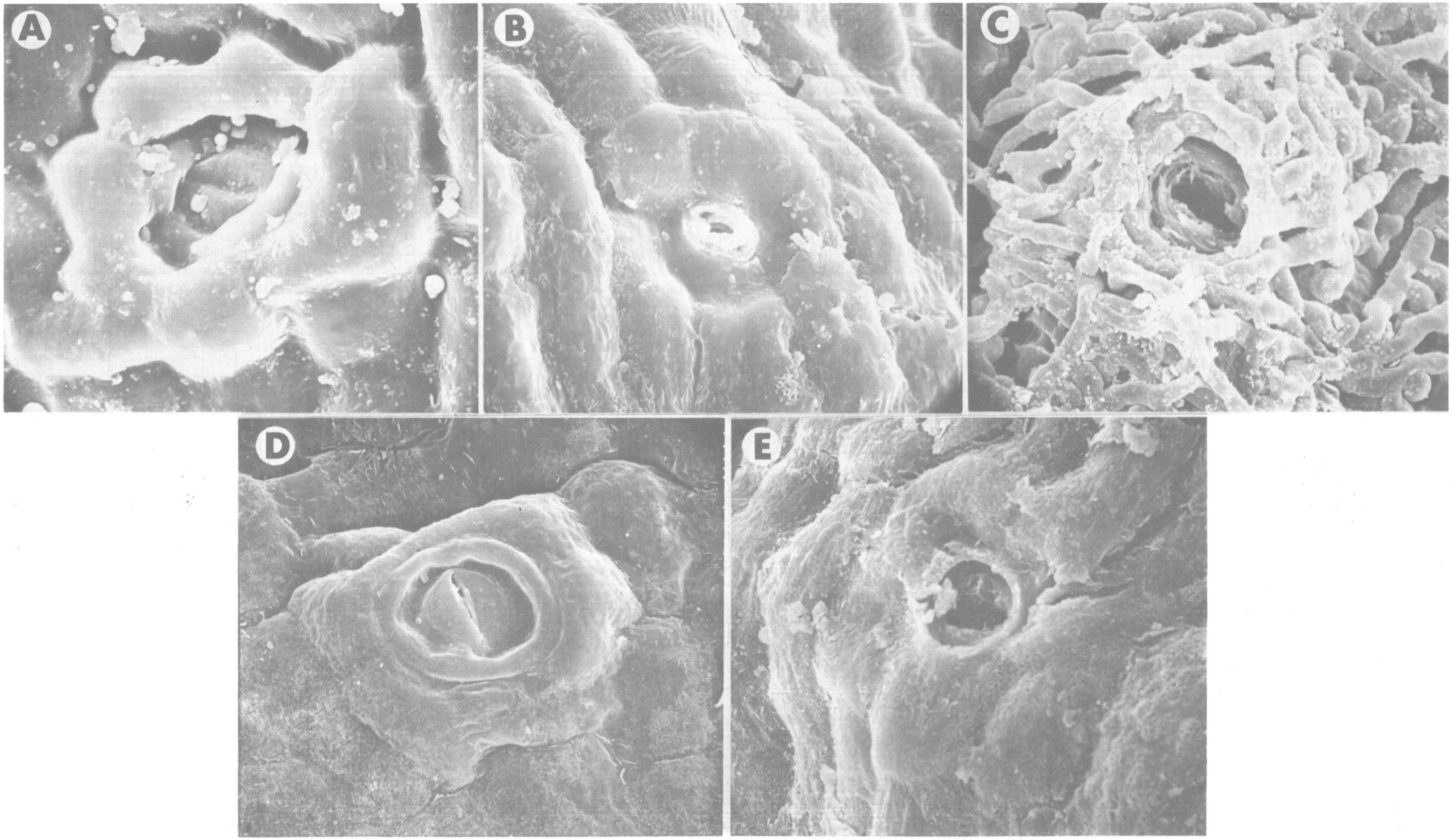

FIG. 2.—Stomates from Malus bud scales. (A) M. zumi 'Calocarpa' x 200; (B) M. sargentii x 2000; (C) M. robusta x 2000; (D) M. baccata var. mandshurica x 2000; (E) M. baccata x 2000.

guard cells was apparent, while in others wax occluded any aperture and only a depression remained visible.

Subsidiary cells were conspicuously raised above the surrounding cells, affording a marked change in topography. The cell pattern of *M. zumi* 'Calocarpa' consisted of regular, rectangular cells arranged in long, unbroken parallel rows (Fig. 1B).

The surface cells of buds of *M. sargentii* appeared irregular and without definite orientation (Fig. 1C). In contrast to the previous two species, *M. sargentii* had a thicker wax layer and scattered wax pieces, and the cellular topography was more rugged. Again, stomates were most easily located by their subsidiary cell groupings, which varied in number from two to five cells (Fig. 2B). In most instances the stomatal apparatus appeared raised above surrounding cells as in *M. zumi* 'Calocarpa', but in *M. sargentii* the stomatal apparatus was less uniform and definitive. Guard cells were rarely seen because of wax occlusions in the openings. *M. sargentii* stomatal units consistently exhibited a ring or rim of wax around the opening that often charged just enough to appear lighter than the surrounding surface.

The only species that displayed distinctive wax structure was *M. robusta* (Fig. 1D). From tip to base the entire bud was heavily encrusted with a fibrous wax. The cell pattern was completely obscured except in small areas were the wax had been torn away. Again, the stomatal units were quite distinctive (Fig. 2C). The subsidiary cells were found to project some distance above the scale surface, forming a rounded stub. Almost all of the stomates observed were blocked by wax particles and were nearly buried in fibrous wax.

The stomatal units of the last species examined, *M. baccata* var. *mandshurica,* showed less consistency than those previously discussed. Scales nearest the bud tip exhibited very unique structures consisting of five to seven subsidiary cells surrounding a sunken pair of guard cells (Fig. 2D). Bud scales below the tip were generally covered by a thick wax layer, rendering the stomatal units less discernible (Fig. 2E). On these scales the subsidiary cell grouping can still be seen around a distinct aperture, but guard cells were rarely observable. Here again, the cell pattern was regular and fairly flat, with a tendency toward parallel cell rows in some areas (Fig. 1E).

This limited beginning indicates that similar plant species can be distinguished through establishment of consistent surface morphological detail. In this particular study of crabapple species, the best identifying characteristics were found to be stomatal structure and cell pattern. The optimum bud areas for observation were scales nearest the bud tip, since they appeared to be less affected by wax build-up due to aging. Differentiating cultivars within a species is the next logical step in this research program.

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Sex Attractants: A New Warning System to Time Clearwing Borer[1] Control Practices

DAVID G. NIELSEN and FOSTER F. PURRINGTON[2]

INTRODUCTION

Traditionally, borers have been the most destructive insect pests of woody plants for which there have not been reliable control measures. Factors responsible for this include: 1) larvae are vulnerable only from hatch until they burrow beneath the bark, 2) eggs are deposited over several weeks and sometimes months, and 3) seldom is enough known about the seasonal histories of borers in a given area to know when and how often insecticidal sprays should be applied.

Chlorinated hydrocarbon insecticides, including DDT, dieldrin, and lindane, have been used with some success due to their long residual effectiveness. One application could be made early and yet kill larvae hatching 1 or more weeks later. The Environmental Protection Agency has banned DDT and dieldrin and issued a lindane RPAR (rebuttable presumption against registration), which means that the latter may soon be restricted or banned. Consequently, if borer damage to nursery and landscape trees and shrubs is to be minimized, shorter-lived insecticides (including organophosphates and carbamates) must be used more efficiently or alternative control methods must be devised.

Two isomers of 3,13-octadecadien-1-ol acetate (ODDA) have been shown to be sex attractants (pheromones) for lesser peachtree borer, *Synanthedon pictipes* (Grote and Robinson), and peachtree borer, *S. exitiosa* (Say) (4). Observed intergeneric sex attraction (1) suggested that compounds identified as sex attractants for one clearwing moth may also be attractive to others. This paper summarizes the authors' efforts to develop methods of monitoring adult borer flight periods which will lead to efficient spraying schedules.

METHODS AND MATERIALS

Fractions of pheromone gland extract obtained from female lesser peachtree borer adults were field-bioassayed in glass dishes by recording responses of male clearwing moths. Similar bioassays were conducted with synthetic ODDA and later with corresponding alcohols (ODDOH). Pherocon 1C traps, baited with single isomers of ODDA or ODDOH or in various combinations, were placed in orchards, cemeteries, nurseries, golf courses, and woodlands. Captured clearwings were sent to Dr. T. D. Eichlin[3] for identification. Pheromone fractions and synthetic hydrocarbons were supplied by Dr. James H. Tumlinson[4]. This work was accomplished and is continuing with the assistance of entomologists and other professionals in several eastern states from New York to Florida and Oregon and Washington in the West.

RESULTS AND DISCUSSION

Bioassay of pheromone extract confirmed the speculation that clearwing moths share pheromone components (3). In fact, a fraction of lesser peachtree borer extract that was unattractive to lesser peachtree borer males attracted two different species of clearwing moths, *S. rileyana* (Hy. Edwards) and *Podosesia aureocincta* Purrington and Nielsen (3). Although this component has not been characterized chemically, trapping studies with all ODDA's and ODDOH's indicate that this unidentified fraction from lesser peachtree borer female abdominal tips is an alcohol (unpublished data).

Trapping studies ultimately provided information helpful to developing sex attractants for many economically important clearwings (Table 1). Some of these attractants have been provided, along with sticky traps, to growers and arborists who have then used trapping information to time application of pesticidal sprays. The first thorough coverage spray is applied approximately 7-10 days after first males are captured. Trap captures are monitored weekly, and a second spray is applied if flight continues for more than 6 weeks.

A single well-timed spray provides protection against lilac borer, *P. syringae* (Harris), and an oak borer, *Paranthrene simulans* (Grote), that commonly attacks pin oaks in Ohio. Dogwood borer, *S. scitula* (Harris), and lesser peachtree borer emerge over a period of several months in Ohio (ca. May to early September), necessitating at least two applications of an effective insecticide (see Ohio Coop. Ext. Serv. Bull. 504 for control recommendations). Peachtree borer emergence in northeast Ohio begins in late June and continues through early September, so two timely applications should provide protection against this species.

[1]Lepidoptera: Sesiidae.

[2]Associate Professor and Technical Assistant, Dept. of Entomology, Ohio Agricultural Research and Development Center.

[3]California Department of Food and Agriculture, Sacramento, California 95814.

[4]USDA, ARS, Insect Attractants, Behavior and Basic Biology Research Laboratory, Gainesville, Florida 32604.

TABLE 1.—Attractants Suitable for Monitoring Flight Activity of Selected Clearwing Moths.

Scientific Name	Common Name or Host	Attractant (isomer(s))	(ratio of isomers)
Paranthrene simulans	Oak	cis,cis-3,13-ODDA	
Podosesia syringae	Lilac Borer	cis,cis-3,13-ODDA	
Podosesia aureocincta (2)	Ash	cis,cis-3,13-ODDA trans,cis-3,-13-ODDA cis,cis-3,13-ODDOH	(20) (1) (3)
Paranthrene tabaniformis	Willow and Poplar	cis,cis-3,13-ODDA trans,cis-3-13-ODDOH	(1) (9)
Albuna fraxini	Virginia Creeper	trans,cis-3,-13-ODDA cis,cis-3,13-ODDOH	(1) (3)
Synanthedon exitiosa	Peachtree Borer	cis,cis-3,13-ODDA trans,cis-3,-13-ODDA	(19) (1)
Synanthedon fatifera*	Viburnum	cis,cis-3,13-ODDA trans,cis-3,-13-ODDA cis,trans-3,13-ODDA	(36) (1) (1)
Synanthedon fulvipes*	Alder	cis,cis-3,13-ODDA trans,cis-3,-13-ODDA cis,trans-3,13-ODDA	(36) (1) (1)
Synanthedon pictipes	Lesser Peachtree Borer	trans,cis-3,-13-ODDA	
Synanthedon scitula	Dogwood Borer	cis,cis-3,13-ODDA	
Synanthedon acerni	Maple Callus Borer	cis,cis-3,13-ODDA trans,cis-3-13-ODDOH	(9) (1)

ODDA = octadecadien-l-ol acetate.
ODDOH = octadecadien-l-ol.
*The role of minor components is unclear, but the attractant used to capture this species contained these isomers, so they are presented here.

Although clearwing moth pheromone traps are not yet available commercially, the authors have used them at cooperating nurseries to monitor borer emergence, permitting precise timing of control measures. This practice greatly improves borer control and reduces the number of insecticide applications necessary to prevent damage.

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Nematicidal Dips for Control of Root-knot Nematodes on Astilbe, Hosta, and Iris

C. C. POWELL and R. M. RIEDEL[1]

INTRODUCTION

The root-knot nematode (*Meloidogyne* spp.) has a wide host range including many ornamental plants grown in Ohio. Root-knot nematodes cause plants to form root galls which destroy root function. Plants supporting heavy infestations of these nematodes are severely stunted, more susceptible to water stress, and exhibit symptoms of mineral deficiencies.

Meloidogyne hapla, the northern root-knot nematode, is frequently found in Ohio nursery soils (authors' unpublished data). This nematode can be controlled in soils prior to planting by a wide range of soil fumigants. However, since the female root-knot nematode lives within the tissues of infested roots and other underground plant parts, clean, uninfested plant parts must be set into fumigated soil to bring about control of root-knot nematodes.

Many ornamentals important in Ohio are propagated from corms, rhizomes, or vegetative cuttings of stock plants. Control of *Meloidogyne* in vegetative propagules is difficult because there is a limited range of nematicides which are safe (non-phytotoxic) to living plant tissues. Ethoprop and fensulfothion have been used successfully to control southern root-knot when applied to *Gerbera jamesonii* as a bare root dip (3). Fensulfothion, ethoprop, and oxamyl have been suggested for control of several different genera of endo-parasitic nematodes, including root-knot, when applied as a bare root or tuber dip treatment to foliage plants (1). Stem nematodes were controlled in bulbous iris propagules with dips of aldicarb (2).

The purpose of the study reported in this paper was to examine the efficiency of several chemicals applied as dips for control of root-knot nematode on astilbe, Japanese iris, and hosta.

[1]Associate Professors, Dept. of Plant Pathology, The Ohio State University and Ohio Agricultural Research and Development Center.

MATERIALS AND METHODS

Astilbe divisions (variety Reingold) were dipped on either Dec. 18, 1973 (the winter preceding planting) or on April 18, 1974 (just prior to planting). The December treated divisions were stored in plastic bags at 40° F until planting in April. Starts of Japanese iris (variety Mahogany) and *Hosta fortunii* (variety Hyacinthi) were treated only on April 18.

Forty to 60 starts were treated with each treatment by dipping them in the chemicals for 10 minutes. They were drained briefly but not rinsed after treatment. Chemicals used were carbofuran (Furadan 4F, FMC Corp.), oxamyl (Vydate 2 LC, duPont Chemicals Co.), phenamiphos (Nemacur 3 EC, Chemagro Chemical Co.), ferisulphothion (Dasanit 6 EC, Chemagro Chemical Co.), and DBCP (Nemagon 12.1% EC, Shell Chemical Co.). All material was planted into fumigated ground on April 20. Each treatment was divided into replicates of 10 plants each, randomized in the planting bed. On Sept. 25, 1974, ratings of growth and numbers of plants surviving were made. Plants were dug and brought into the lab for root-knot evaluations.

TABLE 1.—Survival and Growth of Astilbe Divisions Dipped in Nematicides in Winter and Stored Until Spring.

Treatment	Dosage*	Number of Survivors†	Growth Results
Carbofuran	500 ppm	6	Poor
Carbofuran	1000 ppm	9	Poor
Oxamyl	600 ppm	8	Good
Oxamyl	1200 ppm	9	Poor
Phenamiphos	500 ppm	8	Good
Phenamiphos	1000 ppm	5	Poor
Ferisulphothion	500 ppm	8	Good
Ferisulphothion	1000 ppm	5	Good
DBCP	(1.5 gal/100)	2	Poor
DBCP	(3.5 gal/100)	1	Poor
Check		2	Poor

*Divisions were treated for 10 min, drained briefly, and put in plastic bags on Dec. 18.
†Divisions were planted on April 20 and observed on Sept. 25. Forty divisions per treatment were treated and planted in four replicates.

TABLE 2.—Effects of Preplant Nematicidal Dips on Astilbe Divisions and Root-knot Control.

Treatment	Dosage*	Number of Survivors†	Growth Results	Root-knot Rating‡
Carbofuran	500 ppm	30	Poor	1.4
Carbofuran	1000 ppm	43	Good	2.6
Oxamyl	600 ppm	43	Fair	2.6
Oxamyl	1200 ppm	45	Good	2.1
Phenamiphos	500 ppm	48	Good	2.3
Phenamiphos	1000 ppm	42	Good	1.8
Ferisulphothion	500 ppm	40	Poor	2.2
Ferisulphothion	1000 ppm	45	Good	2.5
Check		40	Good	2.6

*Divisions were dipped for 10 min, drained briefly, and stored in plastic bags on April 18 until planting.
†Divisions were planted on April 20 and observed on Sept. 25. Fifty divisions per treatment in five replicates for each treatment.
‡Root-knot infestation was rated on a 1 to 3 scale, with 1=no galls, 2=1 to 10 galls, 3=more than 10 galls.

RESULTS

The survival of the December dipped astilbe was very poor, even in the checks (Table 1). Evidently the storage conditions were faulty. Several of the treatments did improve the survival rate and resulted in more vigorous plants. However, this may have been due to control of storage pests in addition to root-knot nematodes. Sample digging did show root knots on the checks and fewer in the treatments. The low number of surviving plants prevented getting good data, however.

The astilbe divisions treated in the spring were taken from lots stored from fall harvest by the grower. As compared to the winter treated lots, the survival rate of these plants was much greater in September (Table 2). The treatments did not appear to adversely affect the survivability or growth of the plants. Plants in two treatments did appear to grow poorly, but this did not seem to result from phytotoxicity or nematode infection. Nematode symptoms were generally reduced by the treatments, although no treatment completely eradicated the pest.

Examination of the Japanese iris and hosta plants in September indicated no root-knot nematode symptoms even in the checks. The material may not have been infested. Perhaps the disease just failed to develop in the first season. Survival and growth results would indicate that carbofuran or oxamyl would be the safest materials to use (Table 3). However, none of the treatments except the high rate of ferisulphothion appeared to damage the plant material. The survival of the Japanese iris was increased a bit by treatment, as with the first astilbe experiment (Table 1). Again, such a result could have been because of control of soil insects or other pests.

DISCUSSION

A more intensive study is needed to determine the best programs for nematicidal root-knot control dips on these plants. This preliminary study gave indications that such a control approach will be suc-

TABLE 3.—Effects of Preplant Nematicidal Dips on Japanese Iris and Hosta.

Treatment	Dosage*	Number of Survivors		Growth Results	
		Japanese Iris	Hosta	Japanese Iris	Hosta
Carbofuran	500 ppm	30	56	Poor	Fair
Carbofuran	1000 ppm	31	47	Excellent	Good
Oxamyl	600 ppm	31	54	Excellent	Good
Oxamyl	1200 ppm	31	56	Good	Good
Phenamiphos	500 ppm	29	56	Good	Fair
Phenamiphos	1000 ppm	29	54	Good	Fair
Ferisulphothion	500 ppm	32	53	Good	Fair
Ferisulphothion	1000 ppm	31	52	Poor	Fair
Check		24	55	Good	Fair

*Starts were dipped for 10 min, drained briefly, and stored in plastic bags on April 18 until planting.
†Starts were planted on April 20 and observed on Sept. 25. For Japanese iris, 40 starts per treatment in four replications; for Hosta, 60 starts per treatment in six replications.

cessful. The failure to provide complete root-knot nematode control on the spring-dipped astilbe suggests that higher rates or longer dipping times should be researched. The lack of phytotoxicity of carbofuran or oxamyl at tested rates demonstrates that there is a margin of safety present as one goes toward higher dosages.

Faulty storage prevented acquisition of much of the data that could have come from the winter dipping program. Fall dipping does not appear to cause damage to the plant material. Improved efficacy may result from winter dipping and further storage prior to planting.

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Fungicides and the Control of Diseases on Ornamental Plants: Results of Research Trials

C. C. POWELL[1]

INTRODUCTION

Many chemical pesticides used on ornamental plants for disease control are used in violation of federal pesticide law! The law states that any "use inconsistent with the label" is illegal. In ornamentals, there are hundreds of plants and diseases. Naturally, pesticide labels do not often list each plant-disease combination. However, it is common knowledge that certain chemicals are safe and effective on the unlabeled plant disease being dealt with. Thus, many will use the material in spite of the law—because there is no other choice in many cases!

Mission-oriented researchers must attempt to rectify this illegal use situation. In reviewing these results, it will be noted that research is going on with old as well as new materials. Data providing the performance of older materials will provide the basis for expansion of labels to make more uses legal. Of course, work with experimental materials is also vital to the continued development of pesticides which are more effective, safer to plants and applicators, and less damaging to the environment.

Powdery mildews continue to severely blemish and perhaps even kill many ornamental plants each year. Materials currently available are often not adequate. Thus, many of the experiments reported here are concerned with new chemicals being developed for powdery mildew control.

Other experiments have as a primary goal the improvement of control by stricter attention to timing of the initial and follow-up applications of pesticides. Most fungicides act preventatively. They must be applied before infection. However, it is inefficient and costly to apply them during times when infection is not likely. Many times throughout the season, the environment is limiting the action of the fungus pathogen. Also, the host plant may be susceptible to infection only at certain times of the year.

[1]Associate Professor, Dept. of Plant Pathology, The Ohio State University and Ohio Agricultural Research and Development Center.

CRABAPPLES—POWDERY MILDEW

Although some cultivars of crabapples are damaged by powdery mildew, the disease is more troublesome on many seedling cultivars used as rootstock. The disease limits the vigor of the rootstock and decreases the successful union and performance of the cultivars budded or grafted onto them. In this experiment, 1-year-old apple seedlings were planted out 12 inches apart in 80-foot rows. Sprays were applied only once a month, on June 23, July 28, and August 27. A 2-gallon compression sprayer was used to spray the trees to runoff. Three replicates of 10 trees each for each treatment were randomized in the rows.

Mildew severity was observed twice (Table 1). The results were similar at both times. Monthly spray intervals are generally not considered adequate to completely control powdery mildew. However, the objective was maintaining reasonable vigor in the plants as opposed to complete cosmetic control of all signs of the disease. Thus, the Benlate plus Triton B-1956 (a spreader-sticker) results are more than acceptable. The PP 588 (at the high 32 oz rate) and the EL 222 results are also quite good. Dodemorph

TABLE 1.—Control of Powdery Mildew on Crabapple Understock.

		Disease Severity*	
Treatment	Rate per 100 Gallons	July 26, 1976	Sept. 28, 1976
Benlate 50 WP + Triton B-1956	8 oz + 8 oz	1.6 a†	1.3 a
PP 588 25 EC	32 oz	2.5 b	1.7 a
EL 222 12.5 EC	2.4 oz	2.7 bc	1.9 ab
Zyban 15-60 WP + Triton B-1956	1.5 lb + 8 oz	2.8 bcd	2.9 de
Zyban 15-60 WP + Triton B-1956	3 lb + 8 oz	2.9 bcde	2.6 cd
EL 222 12.5 EC	4.5 oz	2.9 bcde	2.0 abc
PP 588 25 EC	16 oz	3.4 cdef	2.8 de
Dodemorph 43%	32 oz	3.5 cdef	2.6 cd
FORE 80 WP + Triton B-1956	18 oz	3.6 def	3.2 ef
EL 222 12.5 EC + Exhalt 800	2.4 oz + 8 oz	3.7 ef	2.4 bcd
Check		4.1 f	3.6 f

*Disease severity was rated on a 0 to 5 scale, with 0=no disease and 5=maximum severity over all foliage.
†The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

is a mildicide with little residual activity. Thus, monthly spray intervals were too long for adequate control. FORE is a fungicide not generally considered active against powdery mildew. This inactivity was seen here as well.

ROSES—POWDERY MILDEW

A second powdery mildew test was conducted on roses. Most hybrid tea roses are susceptible to this disease and must be sprayed to achieve adequate growth and flower quality. Command Performance roses were planted in three rows on 4-foot centers in April. Mildew appeared on July 15. Sprays were applied to runoff using a 2-gallon compression sprayer on July 28, August 12, and August 30. Each treatment was replicated three times, with five plants in each block randomized throughout the rows.

Several materials are already registered for control of this disease on roses. In this experiment, only experimental chemicals were being used. Mildew severity was rated on Sept. 28, 1 month after the final spray (Table 2). The EL 222 was the only chemical that gave excellent control. Moderate control was achieved by the other materials. OCC 6219 is an "all purpose spray" made up of a miticide, a general insecticide, and a broad spectrum fungicide. It appears as though this material may have to be sprayed more frequently than once every 2 weeks to control powdery mildew on outdoor roses.

LILAC—POWDERY MILDEW

Many of the newer hybrid dwarf lilacs are quite susceptible to powdery mildew. Little information is available to indicate which varieties are resistant. Thus, chemical spray programs may become necessary to maintain a planting properly. This experiment was conducted to see if control could be realized with only two sprays during the entire summer. A mildew susceptible lilac hedge of uncertain cultivar showed signs of beginning mildew infestation on July 15. Sprays were applied to runoff using a 2-gallon compression sprayer on July 28 and on August 27. Three replications of 8-foot hedge sections were randomized per treatment. Mildew incidence was observed and rated on Sept. 28 (Table 3).

EL 222 and Daconil 2787 provided good control, except that the Daconil 2787 was toxic to the plants at this rate. The other materials provided only moderate control, indicating that more frequent sprayings might be necessary. FORE, a fungicide not designed for powdery mildew control, would not be expected to control the disease even at closer spray intervals.

TABLE 2.—Powdery Mildew Control Trial on 'Command Performance' Roses.

Treatment	Rate per 100 Gallons	Disease Severity*
EL 222 12.5 EC	4.5 oz	1.3 a†
Zyban, 15-60 WP + Triton B-1956	1.5 lb + 8 oz	2.2 b
PP 588 25 EC	16 oz	2.7 c
OCC 6219, 4—3.25—3 EC	104 oz	2.9 c
Check		4.0 d

*Disease severity was rated on a 0 to 5 scale, with 0= no disease and 5=max'mum disease on all foliage.

†The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

TABLE 3.—Control of Powdery Mildew of Lilac with Two Sprays Only.

Treatment	Rate per 100 Gallons	Disease Severity*
Daconil 2787 6F	3 pints	1.0 a†
EL 222 12.5 EC	4.5 oz	1.3 a
EL 222 Oil 1.5 EC	35 oz	1.7 a
Zyban 15-60 WP + Triton B-1956	3 lb + 8 oz	2.3 ab
Dodemorph 43 EC	32 oz	2.3 ab
PP 588 25 EC	32 oz	2.3 ab
Zyban 15-60 WP + Triton B-1956	1.5 lb + 8 oz	2.7 ab
PP 588 25 EC	16 oz	3.0 abc
EL 222 Oil 1.5 EC	35 oz	3.0 abc‡
Benlate 50 WP + Triton B-1956	8 oz + 8 oz	3.3 abc
FORE 80 WP + Triton B-1956	18 oz + 8 oz	4.3 bc
Check		5.0 c

*Disease severity rated on a 0 to 5 scale, with 0=no disease and 5=maximum severity. The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

†Phytotoxic; severe leaf burn.

‡This treatment applied on August 27 only.

CHRYSANTHEMUM AND RIEGER BEGONIA—PHYTOTOXICITY OF MILDICIDES

Many flower plants become unsightly in the landscape because of infection by powdery mildews, usually in late summer. Some mum and Rieger begonia varieties fall into this category. Spraying these plants when in flower can be harmful because of damage due to the spray. In these greenhouse trials, two biweekly sprays were applied to the mums on August 10 and 25. Five biweekly sprays were applied to the begonias from June 23 through August 18.

The mums were observed for damage on Sept. 3 (Table 4). Zyban was seen to produce a noticeable spray residue. Dodemorph appeared to slightly malform very young leaves on one of the two varieties in the test. Stunting was the main effect noted upon spraying the begonias with mildicides (Table 5). In addition, the Dodemorph produced a very slight flower burn on treated plants.

TABLE 4.—Phytotoxicity of Mildicides Sprayed on Frista and Senorita Chrysanthemums.

Treatment and Rate per 100 Gallons	Observation
Checks	OK
Zyban 15-60 WP, 1 ½ lb + B-1956, 8 oz	Residue noticeable
Zyban 15-60 WP, 3 lb + B-1956, 8 oz	Residue undesirable
Benlate 50 WP, 8 oz + B-1956, 8 oz	OK
FORE 75 WP, 18 oz + B-1956, 8 oz	OK
Dodemorph 43 EC, 64 oz	Young leaves malformed on Senorita only
Dodemorph 43 EC, 32 oz	Young leaves slightly malformed on Senorita
PP 588 25 EC, 32 oz	OK
PP 588 25 EC, 16 oz	OK
EL 222 12.5 EC, 2.5 oz	OK
EL 222 12.5 EC, 5 oz	OK

ROSE—BLACKSPOT

This disease is probably more common on garden roses than the powdery mildew disease mentioned earlier. Control of this disease is difficult with fungicides. Sprays must be started before there is any sign of the disease. Spray intervals of 2 weeks or less must be maintained all summer except during periods of drought and no overhead irrigation to splash water about. Peace rose plants in rows on 3-foot centers were sprayed every 2 weeks from June 17 through August 30 with a 2-gallon compression sprayer. Each treatment consisted of three blocks of five plants each randomized in the rows.

Disease severity was rated on July 26 and Sept. 28 (Table 6). The September observation was 1 month after the final application. Phaltan is registered for control of this disease, but performed poorly here later in the season where residual effect was needed. OCC 6219, the combination insecticide-miticide-fungicide, provided excellent disease control, even 1 month after the final application.

FIRETHORN—SCAB

The scab disease on firethorn is seen on the leaves and fruit. It is hardly noticeable on leaves except in

TABLE 5.—Effects of Mildicides Sprayed on Schwabenland Red Variety of Rieger Begonias.

Treatment and Rate per 100 Gallons	Average Height - cm
Baymeb 6447, 25 WP, 2.8 oz	11 a*
Baymeb 6447, 25 WP, 1.4 oz	12 ab
EL 222 12.5 EC, 4 oz	14 b
EL 222 12.5 EC, 2 oz	17 c
PP 588 25 EC, 8 oz	19 cd
Check	21 de
Dodemorph 43 EC, 16 oz	21 de
PP 588 25 EC, 4 oz	22 ef

*The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

TABLE 6.—Control of Blackspot on Peace Rose.

Treatment	Rate per 100 Gallons	Disease Severity* July 26, 1976	Disease Severity* Sept. 28, 1976
OCC 6219, 4—3.25—3 EC	104 oz	0.8 a†	1.7 a
EL 222 Oil 1.5 EC	52 oz	1.1 ab	3.1 b
EL 222 Oil 1.5 EC	26 oz	1.6 bc	3.8 c
Phaltan 75 WP + Triton B-1956	1 lb + 8 oz	2.2 c	3.8 c
Check		3.9 d	4.7 d

*Disease severity was rated on a 0 to 5 scale, with 0=no disease and 5=maximum severity including defoliated leaves and leaves with lesions.

†The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

production nurseries where frequent overhead irrigation can cause severe epidemics. On the fruit, the disease blackens the berries and is quite undesirable, even in the landscape. The purpose of this experiment was to see if fruit symptoms could be controlled with only two sprays. An 8-year-old hedge was divided into six 8-foot-long replicates for each treatment. Sprays were applied with a 10-gallon power sprayer when the plants were in full bloom (May 15) and again 2 weeks later.

Good disease control on the fruit was noted in almost all the treatments on Sept. 28 (Table 7). Daconil fungicide performed well in both the WP and the flowable form. Benlate is registered for the control of this disease.

VIBURNUM OPULUS COMPACTA—DOWNY MILDEW

Downy mildew diseases are not nearly as common on ornamental plants as the powdery mildews discussed earlier. However, where they do occur, they cause rapid leaf drop and poor plant looks and performance. Susceptible plants in container growing programs are often badly infected because of overhead watering which splashes water about and wets the leaves. In this experiment, nursery plants growing in 2-gallon containers were sprayed to runoff with a 2-gallon compression sprayer every 2 weeks from April 23 through August 30. Each treatment was applied to six randomized blocks of 10 plants each.

On Sept. 15, the amount of defoliation was noted (Table 8). Zyban and FORE provided good control. The disease was not seen until August. Not much is known of the behavior of the fungus. However, these results suggest that it may not be necessary to begin spraying the plants as early in the season as was done here.

ZINNIA—ALTERNARIA BLIGHT

The fungus causing this disease often comes in as a contaminant on seed. Thus, the disease may get started early and become quite serious by midsummer if cool, wet weather prevails. Seed was sown in two 80-foot rows on June 1. Sprays were applied to runoff on July 15, 28, August 12 and 27, using a 2-gallon compression sprayer. Each treatment was applied to three randomized blocks.

Blight was severe on the plants on Sept. 28 (Table 9). Only two chemicals, FORE and Zyban, provided good control. Another common disease of zinnias is powdery mildew. Unfortunately, FORE would not be expected to control this disease as well. Zyban is an experimental fungicide containing mancozeb (as in FORE) and a material like Benlate. Thus, it should control both powdery mildew and Alternaria blight on zinnias.

TABLE 7.—Scab Control on the Fruit of Firethorn.

Treatment	Rate per 100 Gallons	Disease Severity*
Daconil 6F	3 pints	1.0 a†
Benlate 50 WP + Triton B-1956	8 oz + 8 oz	1.2 a
Daconil 50 WP + Triton B-1956	16 oz + 8 oz	1.2 a
Daconil 6F	24 oz	1.2 a
EL 222 Oil 1.5 EC	26 oz	1.8 a
EL 222 12.5 EC	3.2 oz	4.7 b
Check		7.0 c

*Disease severity was rated on a 0 to 10 scale, approximating the percent of fruit surface blackened by scab. 0=no scab, 10=100% of fruit surface infected.

†The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

TABLE 8.—Prevention of Downy Mildew Defoliation on Viburnum opulus compacta.

Treatment	Rate per 100 Gallons	Disease Severity*
Zyban 15-60 WP + Triton B-1956	3 lb + 8 oz	0.7 a†
Zyban 15-60 WP + Triton B-1956	1.5 lb + 8 oz	1.1 b
FORE 80 WP + Triton B-1956	18 oz + 8 oz	1.8 b
Daconil 6F	3 pints	2.6 c
Daconil 6F	1.5 pints	2.7 c
Phaltan 75 WP + Triton B-1956	32 oz + 8 oz	2.8 c
Check		3.7 d

*Disease severity was rated on a 0 to 5 scale, with 0=no disease and 5=maximum defoliation.

†The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

TABLE 9.—Sprays of Zinnia to Control Alternaria Blight.

Treatment	Rate per 100 Gallons	Disease Severity*
FORE 80 WP + Triton B-1956	18 oz + 8 oz	1.3 a*
Zyban 15-60 WP + Triton B-1956	3 lb + 8 oz	1.3 a
Zyban 15-60 WP + Triton B-1956	1.5 lb + 8 oz	1.7 ab
Daconil 6F	1.5 pints	3.3 bc
OCC 6219 4—3.25—3 EC	103 oz	3.3 bc
Triforine 6.5 EC	103 oz	3.3 bc
EL 222 Oil 1.5 EC	26.2 oz	3.7 c
EL 222 Oil 1.5 EC	52.4 oz	4.0 c
Check		4.0 c
Benlate 50 WP + Triton B-1956	8 oz + 8 oz	4.3 c

*Disease severity was rated on a 0 to 5 scale, with 0=no disease and 5=maximum severity.

†The small letters indicate Duncan's multiple range groupings of treatments which do not differ significantly at the 0.05 level.

TABLE 10.—New or Coded Pesticides Used in Reported Control Trials.

Name or Code Number	Formulation	Chemical Name: Common	Chemical Name: Technical	Supplier
Zyban	15-60 WP	15% Thiophanate Methyl + 60% Mancozeb		Mallinckrodt
Dodemorph	43 EC		N-cyclododecyl-2.6-di-methylmorpholine acetate	Mallinckrodt
PP 588	25 EC	Butrimate	5-butyl-2-ethylamino-6-methylpyrimidin-4-yldi-methylsulphamate	ICI-America
EL 222	12.5 EC	Fenarimol	α(2-chlorophenyl)-α-)4-chlorophenyl)-5-pyrimidine-methanl	Elanco Products
EL 222	1.5 Oil EC	Fenarimol	α(2-chlorophenyl)-α-)4-chlorophenyl)-5-pyrimidine methanl EL 222 15.0 g/L Oil 496 g/L	Elanco Products
OCC 6219	4—3.25—3 EC	4% Orthene + 3.25% Triforine + 3% Kelthane		Ortho Division of Chevron Chemical Co
Triforine	3.25 EC	Triforine	N,N'-[1,4-Piperazinediyl-bis(2,2,2 trichloroethyli-dene)] bis [formamide]	Ortho Division of Chevron Chemical Co

The Production of Ground Covers in a Sod-like Manner[1]

RICHARD B. STERRETT and T. DAVIS SYDNOR[2]

ABSTRACT

Euonymus *(Euonymus fortunei colorata* Rehd.), English ivy *(Hedera helix* L.), and pachysandra *(Pachysandra terminalis* Sub. & Zucc.) were evaluated for their capability to produce a mat of ground cover plants in a sod-like configuration. Euonymus and English ivy produced a satisfactory product in 12 weeks while pachysandra required 16 weeks. Among the seven media evaluated with English ivy as the test plant, pine bark mulch, peatmoss-perlite, and Metro Mix 300 were judged superior in transportability, overall quality, and landscape acceptance to peatmoss-Haydite-perlite, peatmoss-Haydite, peatmoss-sand, and hardwood bark. Euonymus and English ivy sods in pine bark mulch and peatmoss-perlite media were evaluated for landscape establishment. Both species rooted into the soil and established without appreciable loss 6 months after transplanting into the field.

INTRODUCTION

Ground cover plantings can be an important component in a landscape design. However, with the present method of planting on 22-30 cm centers, a period of 2 or more years is needed before ground cover plants produce the solid foliar cover necessary for the plants to function as an integral part of the landscape design. The use of sod-like material would allow the contractor to install a ground cover planting with immediate visual impact.

Decker (2), in a patent-pending process, successfully raised grass sod in a sewage sludge medium on a polyethylene sheet. In a preliminary trial, Sydnor (unpublished data) produced ivy, euonymus, and pachysandra sods in a fiberglass mat with an asphalt paper backing. This technique is not new and has been used for years with various modifications (3).

In a related study on grass sods, Mitchell and Langston (4) found that the use of netting can also result in a more rapid turnover of sod by allowing harvest prior to the time when rhizomes and grass roots are capable of holding the sod intact. Cal Turf, Inc., was able to reduce rye and bluegrass sod production time from 8 to 4 months using this technique (1).

In order for ground cover sods to be produced commercially, they should be produced from readily obtainable materials using standard nursery production techniques. Production could not be considered as complete unless the ground cover sod could be transported safely by truck and transplanted successfully at the landscape site. Costs must also be considered and are the subject of another study (5).

STUDY I—POTENTIAL FOR PRODUCING A SOD

In the first study, English ivy, euonymus, and pachysandra were evaluated for their potential in producing ground cover sods. A completely randomized split plot design with four replicates x three species x two spacings was used. The 45 x 75 cm main plots of euonymus, English ivy, and pachysandra were divided into two subsections of 22.5 x 75 cm each to test spacing effects. A 2.5 cm layer of 1 peatmoss:1 perlite (v/v) was placed on a 4 mil polyethylene sheet which was covered with a polyethylene net with 0.8 x 0.8 cm openings. The polyethylene sheeting base suggested by Decker (2) was modified by placing the plastic sheet on a 4° slope to insure adequate drainage.

Shoot tip cuttings 10 cm long were inserted on either 5 or 10 cm centers. Cuttings were rooted under intermittent mist with a mist interval of 6 sec every 6 min decreasing to 6 sec every 30 min as rooting occurred. Nutritional levels of the media were supplemented using a slow release fertilizer (18N-4.0 P-10.8K, 3-month release) at a rate of 3.2 kg/m^3 (4 oz/bu) media. Commercially acceptable fungicides and insecticides were applied as required.

Sections (10 x 10 cm) of euonymus, English ivy, and pachysandra at each density were removed from each replicate after 12 and 16 weeks. Roots and stems were separated from the media, air dried for 3 days at 110° C, and weighed.

All three species produced satisfactory ground cover sods. Spacing at 5 cm generally showed root weights 300% higher than for those at 10 cm spacing (Table 1). Increased root weight could be expected to result in greater resistance of the resulting ground cover sod to handling injury during marketing. Euonymus generally had more roots by weight than either English ivy or pachysandra in the 100 cm^2 harvested sections (Table 1).

Visual observations of the roots taken after 12 weeks showed a more extensive and fibrous root system had developed on euonymus and English ivy cuttings than on pachysandra. Euonymus roots at both

[1]Based on a thesis submitted by the senior author in partial fulfillment of the Master of Science degree, The Ohio State University.

[2]Graduate Research Associate and Assistant Professor, respectively, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

TABLE 1.—Shoot and Root Weight in 100 cm² Sections of Euonymus, Pachysandra, and English Ivy at Different Spacings and Harvested After 12 and 16 Weeks in the Mist Bed.

Species	Cutting Spacing (cm)	Harvested After 12 wk		Harvested After 16 wk	
		Shoot wt (g)	Root wt (g)	Shoot wt (g)	Root wt (g)
Euonymus	10	2.24	0.29	2.18	0.72
	5	4.41	1.46	3.70	2.14
Pachysandra	10	1.63	0.22	1.55	0.29
	5	4.40	0.45	4.11	0.90
English ivy	10	2.73	0.26	3.06	0.27
	5	1.85	0.89	3.04	0.72
LSD 5 %		1.89	0.40	1.28	0.97

the 5 cm and 10 cm spacings had knit the media, plants, and net into a single unit. The ivy at 5 cm spacings and generally at the 10 cm spacings was also judged to have grown together satisfactorily.

After 16 weeks the pachysandra had developed a root system which was well knit at a 5 cm spacing. All spacings of euonymus and English ivy were satisfactory after 16 weeks.

FIG. 1.—English ivy produces a solid foliar cover in 8 weeks.

Differences in root and stem weight, while present, were frequently not statistically significant between the same species harvested after 12 and 16 weeks. This was due, in part, to pruning required to keep ivy and euonymus within the subplot area during the 16-week mist propagation period. Pruning is a normal production practice and necessary to reduce harvesting and handling costs, even if the plots were larger.

Visually no differences were noted in the foliar cover produced at either spacing of euonymus and English ivy. Both spacings produced an attractive unit (Fig. 1). To take advantage of greater production of roots at closer spacing and to reduce costs, a spacing of 7.5 cm on centers is suggested. About half as many cuttings are needed when cuttings are spaced 5 cm on center (25 cm²/plant) as are needed at a 7.5 cm spacing (56 cm²/plant). In addition, it is obvious that production costs will also vary with the species (*e.g.*, rooting rapidity of euonymus > English ivy > pachysandra).

STUDY II— TRANSPORTATION AND ACCEPTABILITY

A second experiment was designed to examine plant quality, shipping tolerance, landscape acceptance, and grower acceptance of plants in seven different media. English ivy was chosen as the test plant based on the market potential of ivy sod and earlier test results. Shoot tip cuttings were stuck at 7.5 cm spacings in one of seven different media: pine bark mulch (3.5-6.5 cm particle size); uncomposted shredded hardwood bark; 1 peatmoss:1 perlite (v/v); Metro Mix 300, a commercial potting medium which contains pine bark and vermiculite as the primary ingredients; 1 peatmoss:1 Haydite (an iron slag byproduct) (v/v); 1 peatmoss:1 Haydite:1 perlite (v/v); 1 peatmoss:1 sand (v/v).

The net openings were increased to 1.6 x 1.9 cm as girdling was noted in one instance when using the

TABLE 2.—Evaluation of English Ivy Sod Grown in Seven Media After Shipment to Three Growers and After Return Shipment to the Authors.

Variable	Mean Rating Score*							
	Pine Bark Mulch	Peat-Perlite	Metro Mix	Peat-Haydite-Perlite	Peat-Haydite	Peat-Sand	Uncomposted Hardwood Bark	LSD (10%)
Condition on arrival	5.0	4.7	4.3	4.0	4.0	3.8	3.3	0.9
Foliage density	4.7	4.5	4.7	3.7	3.5	4.0	3.0	0.9
Foliage color and vigor	5.0	5.0	4.8	4.5	3.5	4.1	3.5	0.7
Overall quality	5.0	4.7	4.5	4.0	3.3	3.8	3.0	1.0
Transporting success	5.0	4.0	4.5	3.7	3.0	3.3	3.3	1.1
Media desirability-production	4.7	4.7	4.8	3.8	3.3	3.3	3.0	1.1
Media desirability-shipping	4.7	4.2	4.7	3.8	3.2	3.2	3.0	1.0
Appearance	4.8	4.7	4.7	4.2	4.2	4.2	3.8	1.0
Landscape desirability	5.0	4.3	4.5	4.3	3.8	4.2	3.7	1.1

*1 = unacceptable, 5 = excellent.

0.8 x 0.9 cm net. The media depth was reduced to 2 cm and after 20 weeks under mist, the plants in each replicate had grown together satisfactorily.

In the spring, after overwintering in a plastic house with 2° C minimum temp, English ivy sod in each medium was crated and shipped by truck to one of three growers. The growers evaluated the ground cover sods and then returned the sods to the authors for a second evaluation. The three growers were asked to rank each medium with the most appropriate rating for each of nine questions (Table 2). A scale of 1 (unacceptable) to 5 (excellent) was used for each question. A factorial design with seven media, two species, and six replications per treatment was used. The two evaluations during the shipment period were combined as replications because an earlier analysis showed no differences between times of evaluation.

Differences in transportability, quality, and landscape desirability of plants grown in the seven media were obtained (Table 2). In general, pine bark, peatmoss and perlite, and Metro Mix produced the best ground cover sods, with all means greater than 4.2. Pine bark rated as producing the most aesthetically desirable product for landscape use and received an excellent rating (5.0) by all evaluators. Sand and Haydite containing media, as well as hardwood bark, were not held together as well by the ivy roots which resulted in poorer transportability ratings (Table 2). Thus pine bark, peatmoss, perlite, and Metro Mix were better for shipping than the other media tested.

STUDY III—LANDSCAPE ESTABLISHMENT

A third experiment was designed to evaluate the ease of establishing euonymus and English ivy sods which had been grown in either a pine bark or 1 peatmoss:1 perlite (v/v) media. The entire bed was sloped as before and covered with a 4 mil polyethylene sheet with holes punched randomly throughout the polyethylene sheet to insure better drainage. Pine lath separated the 45 x 75 cm plots.

The shoot tip cuttings were placed in media 2 cm thick, with a 1.6 x 1.9 cm polyethylene net in the media, and rooted under intermittent mist as before. After 12 weeks, the 45 x 75 cm sods of each ground cover were removed from the mist propagation beds and planted in either full sun or 47% shade. Shade was not uniform and was provided by black polypropylene shade cloth. In addition, another establishment treatment similar to the standard commercial practice of planting rooted cuttings 22 cm on center in 2 cm of hardwood bark mulch was included.

The ground cover plants were watered six times with 2 cm of water at each watering during the first 2 weeks after planting, with natural rainfall being sufficient to prevent excessive drying as the season progressed. Treatments were randomized within the main plots of a split plot design, with 47% shade and full sun being the main plots. Four replicates of each treatment with two media and two exposures were arranged in a completely randomized design.

TABLE 3.—Density of Seven Rooting Media.

Rooting Media*	Density (g/cm^3)
Pine bark mulch	0.25
1 Peatmoss: 1 perlite	0.12
Metro Mix 300	0.39
1 Peatmoss: 1 Haydite	0.60
1 Peatmoss: 1 Haydite: 1 perlite	0.46
1 Peatmoss: 1 sand	0.91
Uncomposted hardwood bark	0.14

*Quantities by volume.

Landscape establishability has been satisfactory. Less than 2% loss was noted the following spring (6 months later) in either sun or shade. A relatively severe winter for Columbus was experienced. Winter injury on English ivy was more severe in the unshaded plots with foliar necrosis on all exposed foliage. Foliar necrosis was present on only 20-50% of the ivy foliage in the shaded plot. No injury was noted on the euonymus in either sun or shade. Establishment of a sod of euonymus or English ivy was found to require maintenance similar to establishing a grass sod.

The earlier economic feasibility study (5) showed that production and installation costs were decreased from 35% to 50% using more conventional systems rather than the sod-like system. This, of course, does not consider establishment or maintenance costs. Visual observations of the weed populations in the establishment plots suggest fewer weeds in the ground cover sods than in conventional mulched ground covers, probably due to the increased shading resulting from the complete foliar cover of the ground cover. This problem, as well as storage, handling, overwintering, and other possible ground cover plants, require further investigation.

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An Investigation into the Cause of Conifer Damage in Nursery Storage

ELTON M. SMITH, GARY A. THEIL, and CYNTHIA D. MITCHELL[1]

INTRODUCTION

On occasion, commercial nurserymen have experienced plant injury following storage of balled and burlapped (B & B) and possibly container-grown evergreens under poly-covered structures. The injury is generally manifested as yellow to brown foliage in the center of the plant, often accompanied by partial defoliation. Those plants which look excellent from above when looking into a storage structure are often unsaleable by March or early April when removed from storage. The damage when present has been attributed to a lack of adequate space between plants in storage. The most often mentioned suggestions as to the specific causes of this damage are a lack of adequate light and high concentrations of gases (3).

To determine whether a lack of light would cause this damage, Fleming (2) stored conifers under black plastic and noted an overall improvement in foliage color. In a similar study, Rizzo (6) stored evergreens in structures with light levels from 10 to 100% shade and recorded optimum plant quality under the darkest conditions.

Ethylene accumulation in greenhouses has been recorded at levels of 10-16.3 ppb without plant injury; however, when concentrations increased to 34.1 and 263 ppb, injury to florist crops was noted (5). Lesions developed in pear seedling stems during storage when ethylene levels ranged from 0.5 to 1.0 ppm (1). Carbon dioxide (CO_2) has been reported to cause plant phytotoxicity at 20,000 ppm and nitrogen dioxide (NO_2) at levels from 0.5 to 25 ppm (4).

The specific objective of this study was to determine if typical evergreen storage injury was related to plant spacing, low light conditions, and/or to the presence of specific gases.

MATERIALS AND METHODS

The study was conducted in a 100 x 14', single layer poly-covered quonset structure located in the container research nursery at The Ohio State University. Plants were placed in storage Dec. 15, 1976, and removed April 21, 1977.

The plant materials were *Taxus media* 'Browni' and *Thuja occidentalis* 'Globosa', both 24-30" in diameter. In the spacing study, one treatment consisted of plants spaced with the branch ends touching while in another treatment the plants were put as close together as possible without damaging the shoots. In the dark treatment, black poly film was used to completely enclose the plants. In the light treatment, no additional poly was placed over the plants. A total of 15 plants of both Taxus and Thuja were used in each of the spacing and light treatments of each species.

Ethylene and carbon dioxide samples were removed twice a month from February-April from the center of each treatment with a syringe and measured in a Packard Model 417 Becker gas chromatograph. Hydrocarbons were sampled weekly from early March through mid-April from the center of each treatment and measured in a Bendix hydrocarbon analyzer. Nitrogen oxide gases were measured in the same fashion in a Monitor Labs nitric oxides analyzer. Both analyzers were located in the storage house and samples were drawn by placing plastic tubing into the area to be sampled.

Plant damage was recorded on April 21, 1977, and expressed on a visual evaluation using a scale of 1-5, with 1 = no injury, 2 = light green foliage, 3 = light yellow foliage, 4 = dark yellow or light brown foliage, and 5 = brown foliage or leaf defoliation.

RESULTS AND DISCUSSION

Considerable plant injury was observed on plants in the spacing study. Generally, foliage was a lighter green color when given normal or loose spacing with foliage just touching. However, when the plants were placed in close spacing, greater damage was recorded (Table 1). This injury was manifested as an

TABLE 1.—Effects of Light and Plant Spacing on Phytotoxicity of Taxus and Arborvitae During Winter Storage.

	Phytotoxicity*	
	Arborvitae	Taxus
Light Treatment		
Full light	3.3†	3.2
Darkness	2.8	3.4
Spacing treatment		
Tight spacing	3.4	4.3
Loose spacing	2.2	2.3

*Visual scale 1-5 with 1 = no injury, 5 = brown foliage and/or defoliation.

†Each figure represents an average of evaluations from 30 plants following 4 months of storage.

[1]Professor, Nursery Superintendent, and former Agricultural Technician, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

TABLE 2.—Concentration of Ethylene and Carbon Dioxide Within a Poly-covered Structure Used for Overwintering Arborvitae and Taxus.

Treatments	Concentration*	
	Ethylene (ppb)	Carbon Dioxide (%)
Ambient air—outside	17.11	0.037
Tight spacing	12.26	0.036
Loose spacing	14.78	0.037
Tight spacing under black plastic	15.65	0.061
Loose spacing under black plastic	13.67	0.051

*Figures represent average values of six samples from February to April.

increase in the yellow foliage of the arborvitae and a yellow to brown color of the taxus foliage.

There were little differences in phytotoxicity between plants stored in light vs. those in darkness (Table 1). If plants are stored in darkness, it's important to uncover prior to new shoot and leaf growth, to prevent white foliage and etiolation of new growth.

In no treatments were the ethylene levels higher when sampled among the plants than in the outside atmosphere (Table 2). Average levels throughout March and into April varied from 12 to 16 ppb and were below the threshold levels of 34 ppb previously recorded by Humphery (5) as damaging to florist crops.

Carbon dioxide levels did increase in the treatments under black plastic; however, levels were well below 2.0% reported as causing plant damage (4).

Except for nitrogen dioxide which injures plants from 0.5 to 25 ppm according to Hemerick (4), threshold values have not been reported for methane (CH_4), non-methane (Non CH_4), total hydrocarbons (THC), nitric oxide (NO), and total nitrogen oxides (NO_x).

The ambient outside air averaged 4.1 ppm nitrogen dioxide at noon and 2.9 ppm at midnight, while all treatments within the houses were less than those figures. Despite previously reported injurious values of 0.5 ppm (crops not mentioned), it's not likely that the average concentrations of 0.7 to 2.8 were injurious to the conifers since average values in the loose spacing treatment were slightly higher than the tight spacing treatment.

Nitric oxide and total nitrogen oxide concentrations were lower in the poly storage house than outside and very small differences were noted between tight and loose spacings.

Methane, non-methane, and total hydrocarbon values are presented and only slight differences are apparent between outside air, tight and loose spacing treatments.

In summary, both taxus and arborvitae were injured when spaced close together, typical of injury occasionally experienced by commercial producers in poly storage. The injury does not appear to be a direct result of low light as no additional injury was noted in total darkness all winter in comparison to light under a conventional single layer white copolymer. In addition, high concentrations of ethylene, carbon dioxide, nitrogen oxides, or total hydrocarbons do not appear to be the causal agent for this injury since values were not higher in the tight spacing treatments. The values presented may serve as a point of reference for future research with storage gases.

Further investigations are necessary to examine temperature, relative humidity, air movement, and perhaps fungal pathogens as possible causes for conifer discoloration and defoliation when placed in close spacing in winter storage structures.

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TABLE 3.—Gas Concentrations Within a Poly-covered Structure Used for Overwintering Arborvitae and Taxus.

Gases	Concentration (ppm)*					
	Ambient Air Outside		Tight Spacing		Loose Spacing	
	12:00 p.m.	12:00 noon	12:00 p.m	12:00 noon	12:00 p.m.	12:00 noon
THC	2.1	1.2	3.0	3.4	2.1	2.2
CH_4	1.0	0.7	0.9	0.7	1.0	0.8
Non CH_4	1.2	0.6	2.1	2.7	1.2	1.5
NO	5.5	2.2	3.5	2.6	2.8	2.8
NO_2	4.1	2.9	2.1	1.3	1.1	2.8
NO_x	8.8	5.0	5.6	3.8	3.8	5.5

*Figures represent an average of six weekly samples from early March to mid-April.

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A Comparison of Low Pressure and Common Cold Storage of Unrooted Woody Ornamental Cuttings

BARRY A. EISENBERG, THOMAS A. FRETZ, and GEORGE L. STABY[1]

INTRODUCTION

Due to shortages of labor and space during peak periods of propagation, the storage of unrooted cuttings for extended periods of time may become necessary. Deterioration of plant material during storage and reduced plant vigor following removal from storage are among the many reasons why the storage of cuttings has not been accepted commercially. Refrigerated storage has increased the quality of many commodities by reducing: a) respiration, b) pathogen growth, c) unwanted plant growth, d) loss of pigmentation, and e) moisture loss from stored material (13). The beneficial effects of refrigerated storage have been primarily limited to more lignified rather than to softer materials (10). A new refrigerated storage system, termed low pressure storage (LPS), reduces oxygen levels and facilitates gas removal to extend the storage life of lignified tissue for periods longer than earlier achieved in common cold storage (CCS) as well as allows for the storage of less lignified tissue (8).

[1]Graduate Research Associate and Associate Professors, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

Essentially, LPS is a storage system which lowers the partial pressure of all gases in the storage atmosphere (*e.g.*, ethylene, carbon dioxide, oxygen, etc.) to levels low enough to reduce many of the normal metabolic functions within the material (*e.g.*, chlorophyll degradation, production of volatiles, etc.) (5, 7). Lower partial pressures also facilitate the diffusion of gases such as ethylene from the commodity; likewise, toxic gases do not accumulate in the evacuated chamber because of the continuous air exchanges (5, 7). Since ethylene causes leaf abscission (1, 6), the removal of this gas is advantageous. The design of the LPS system also has a simple method for maintaining a high relative humidity (RH).

Low pressure storage at approximately one-sixth atmospheric pressure reduces mycelium growth and sporulation of *Penicillium expansum, Rhizopus nigricans, Aspergillus niger, Botrytis alli,* and *Alternaria* spp. when compared to colonies maintained at atmospheric pressure or under modified atmospheric storage (2.7% O_2, 97.3% N_2) with a partial pressure of oxygen near that of the LPS system (16). Thus, at lower atmospheric pressures, there is a greater reduction in pathogen growth and sporulation. Also, the onset of

TABLE 1.—Genera Which Have Been Stored Using the LPS or CCS Systems.

Genera (reference)	Storage System	Temp °C (when given)	Days in Storage
Aphelandra (4)	CCS	10° (50° F)	12
Aphelandra (4)	LPS	10° (50° F)	23
Azalea sp. (Kurume) (15)	CCS	—0.5 to 4.4° (31-40° F)	70
Begonia Rex (14)	CCS	—0.5 to 4.4° (31-40° F)	0
Chrysanthemum (3)	CCS	—0.5° (31° F)	28
Chrysanthemum (3)	LPS		42 to 94
Dianthus caryophyllus 'Red Gayety' (2)	CCS	0.5° (33° F)	60 to 90
Dianthus caryophyllus 'White Pikes Peak' (2)	CCS	0.5° (33° F)	60 to 90
Dianthus (3)	LPS		300
Hedera (varieties) (14)	CCS	—0.5° (31° F)	35
Impatiens sultana (12)	CCS	5.0° (41° F)	14
Lonicera spp. (11)	CCS	2.2° (34° F)	28
Maranta leuconeura kerchovena (14)	CCS	0.5 to 4.4° (33-40° F)	0
Pelargonium hortorum (8)	CCS	2.2° (34° F)	14
Pelargonium hortorum (8)	LPS	2.2° (34° F)	28
Peperomia minima (14)	CCS	—0.5 to 4.4° (31-40° F)	0
Peperomia obtusifolia (4)	CCS	10° (50° F)	12
Peperomia obtusifolia (4)	LPS	10° (50° F)	23
Philodendron cordatum (4)	CCS	10° (50° F)	12
Philodendron cordatum (4)	LPS	10° (50° F)	23
Populus spp. (11)	CCS	2.2° (34° F)	28
Pothos (Marble and Golden Queen) (4)	CCS	10° (50° F)	12
Pothos (Marble and Golden Queen) (4)	LPS	10° (50° F)	23
Rhododendron (obtusum, ponticum, simsii) (10)	CCS	—0.5° (31° F)	70

pathogen growth is delayed 1 to 3 days with the LPS system as compared to CCS and modified atmospheric storage.

Research on the storage of unrooted cuttings has been sparse with CCS and nearly absent with LPS. Results from numerous experiments on the storage of unrooted cuttings are summarized in Table 1. In general, high quality plant material, fungicide application, and proper control of storage environments are prerequisites for the production of high quality cuttings from storage.

After discussions with propagation specialists, a need to find a way to store woody ornamental cuttings for extended periods was established and experiments were designed to evaluate the feasibility of storing unrooted woody ornamental cuttings for periods up to 9 weeks comparing the LPS and CCS systems. The results of these investigations are reported.

MATERIALS AND METHODS

Tallhedge *(Rhamnus frangula* 'Columnaris), Regel Privet *(Ligustrum obtusifolium* 'Regelianum'), and Compact European Cranberrybush *(Viburnum opulus* 'Compactum') cuttings were removed from field-grown stock at a local wholesale nursery the day of placement into storage. Cuttings were refrigerated for 3 hours at 40° F (4.4° C) before being placed in their appropriate treatments. Each treatment consisted of four replicates with ten observations per replicate. Cuttings were stored in either LPS or CCS for 3, 6, or 9 weeks.

Cuttings in LPS were placed in air-tight, 10-gallon, stainless steel milk cans lined with ¾ in^2 steel mesh to keep materials from coming in contact with the side of the container. A pressure of 1/30 atmosphere was achieved using a vacuum pump and pressures were controlled with a Matheson No. 49 pressure regulator. Incoming air was first drawn through Purafil (which absorbs ethylene), then through a water bath maintained 1 to 3° F above the ambient storage temperature of 34° F (2.2° C) so incoming air would be near 95% RH. Air was exchanged once each hour from the containers. CCS chambers were identical to LPS chambers except they were maintained at atmospheric pressure.

All cuttings received a 30-second dip in Daconil (1 tbsp/3 gal H_2O), were allowed to dry, and then were placed in plastic netting to keep the treatments separate. One set of cuttings was dipped in Daconil, then rooted directly and used as controls. Upon removal from storage, foliage on the cuttings was visually evaluated, then stuck in a 1:1:1 peat:perlite:sand medium (v:v:v) under a 6 min/6 sec mist cycle with bottom heat (80° F) for 6 weeks. Tallhedge cuttings received a hormone powder application containing 0.1% IBA.

After rooting, foliage and root characteristics were evaluated using the two scales below. Data were analyzed as a completely randomized block design and means were separated using Tukey's omega procedure at the 0.01 level of significance.

Foliage Evaluation Index

1.0 = cutting dead
2.0 = leaves completely deteriorated*
3.0 = more than one-half the leaves deteriorated
4.0 = less than one-half the leaves deteriorated
5.0 = one or two leaves deteriorated
6.0 = leaves in good condition, with no loss of turgor

*Deterioration defined as the loss of turgor, yellowing, defoliation, or the appearance of necrotic areas on leaf tissue.

Rooting Evaluation Index

1.0 = cutting dead
2.0 = callus with 1 to 3 roots
3.0 = showing few roots
4.0 = light rooting
5.0 = medium rooting
6.0 = heavy rooting

RESULTS

All species showed a significant treatment x week interaction when survival percentages at removal from storage were evaluated (data not presented). Percent survival of the unrooted cuttings from the LPS treatments declined gradually at each removal date, while the quality of similar plants from the CCS system declined at a rapid rate. No significant differences in percent survival of any of the three ornamental species were apparent after 6 weeks, regardless of the storage system used, but significant differences were noted between LPS and CCS cuttings following 9 weeks of storage. Cuttings of all three ornamental species after 3, 6, and 9 weeks of LPS and from 3 and 6 weeks of CCS had survival percentages of 50% or greater at removal.

All three unrooted ornamental species exhibited a treatment x week interaction when the foliage was visually evaluated at removal. All cuttings from LPS displayed a gradual decline in quality at each removal date, while the quality of cuttings stored in the CCS system declined at a more rapid rate (Fig. 1). Compact European Cranberrybush cuttings did not show a significant treatment x week interaction at removal from storage at the 0.01 level, but did at the 0.05 level. No significant differences in quality between cuttings from the LPS and CCS systems were noted until cuttings were evaluated after the 9-week storage treatment.

All cuttings stored for 9 weeks in either LPS or CCS were of unacceptable quality, regardless of the species tested; however, the material stored in the LPS system was of significantly better quality than similar material stored in CCS (Fig. 1). All material, regardless of condition, was stuck in the propagation bed after removal from storage. Defoliation of unrooted cuttings was the primary disorder observed that limited the storage of woody ornamental cuttings in the CCS system (Fig. 2).

Unrooted cuttings of the three woody ornamental species that survived the 3, 6, and 9-week storage treatments were placed in the propagation bed for 6 weeks to root. A significant treatment x week interaction was observed when percent survival after rooting was evaluated with all species, except unrooted tallhedge cuttings (data not shown). Significant differences in percent survival were noted in cuttings of Compact European Cranberrybush and Regel Privet stored in either the LPS or CCS system from the 6 and 9-week treatments and with the tallhedge cuttings from the 9-week treatment. Survival percentages of all three woody ornamental species were 50% or greater in all of the LPS treatments, while only the 3 and 6-week CCS treatments had similar survival rates.

Patterns similar to those when unrooted ornamental cuttings were evaluated for foliage characteristics at removal from storage (Fig. 1) were apparent when the foliage and root quality characteristics were evaluated after 6 weeks in the propagation bed (Figs.

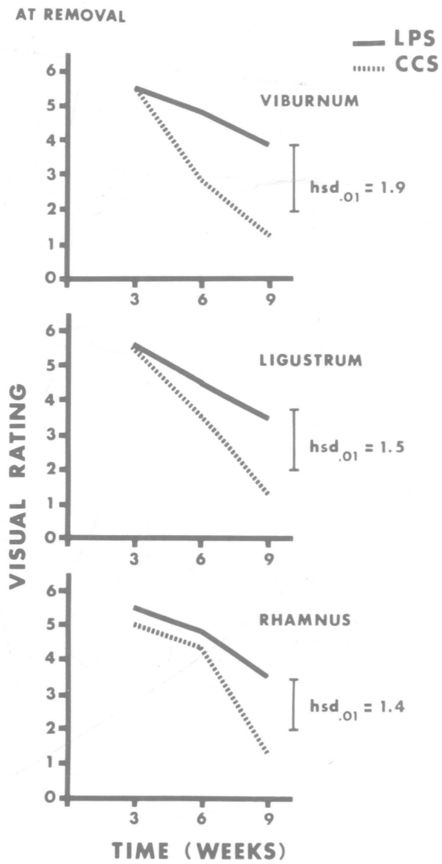

FIG. 1.—Visual evaluation of the foliage of unrooted Compact European Cranberrybush, Regel Privet, and Tallhedge cuttings at removal from either 3, 6 or 9-week LPS or CCS.

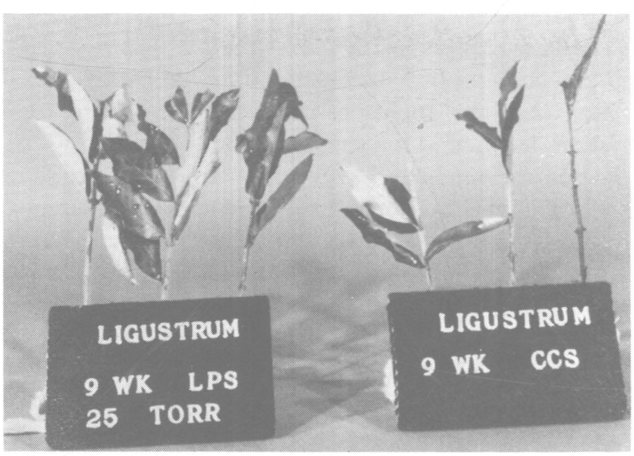

FIG. 2.—A comparison of unrooted Regel Privet cuttings following 9 weeks of storage in either LPS or CCS.

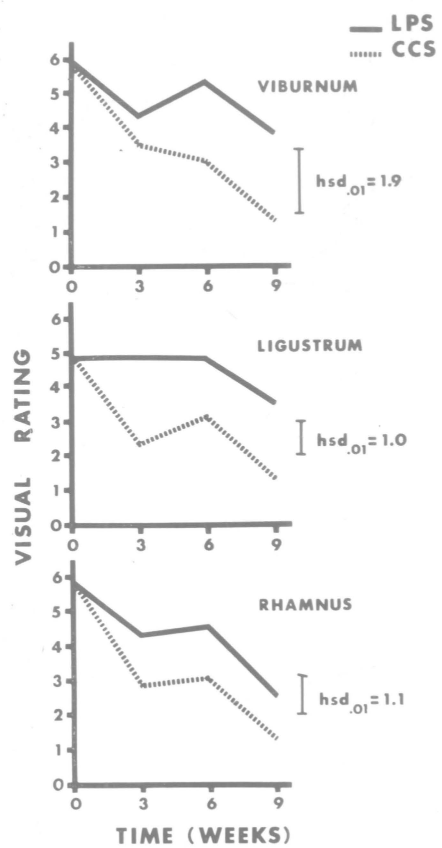

FIG. 3.—Visual evaluation of the foliage of unrooted Compact European Cranberrybush, Regel Privet, and Tallhedge cuttings after 6 weeks in the propagation bed following either 3, 6, or 9 weeks in LPS or CCS.

3 and 4). A similar treatment x week interaction was observed when the foliage of Compact European Cranberrybush and Regel Privet was evaluated (Fig 3). Regel Privet cuttings also showed a significant treatment x week rooting interaction between the storage systems used (Fig. 4). Other species showed similar trends when roots were evaluated, but no significant interactions were apparent at the 0.01 level. All three ornamental species displayed a gradual decline in root system quality at each progressive removal treatment from the CCS system and showed a rapid decline in quality (Fig. 4).

Compact European Cranberrybush and Regel Privet cuttings from either 3 or 6 weeks of LPS and tallhedge cuttings from the 6-week LPS treatment did not differ significantly from control plants when foliage or root development was evaluated after 42 days in the propagation bed (Figs. 3 and 4). In terms of root development, Compact European Cranberrybush cuttings from the 3-week CCS treatment did not differ significantly from non-stored cuttings, directly stuck, after 6 weeks in the propagation bed. All other CCS treatments did show a significant difference from control plants (Fig. 4). Foliage of the Regel Privet cuttings from the 3-week CCS treatment did not differ significantly from controls after 6 weeks in the rooting bed (Fig. 3), but root quality was significantly poorer when compared to the control plants (Fig. 4).

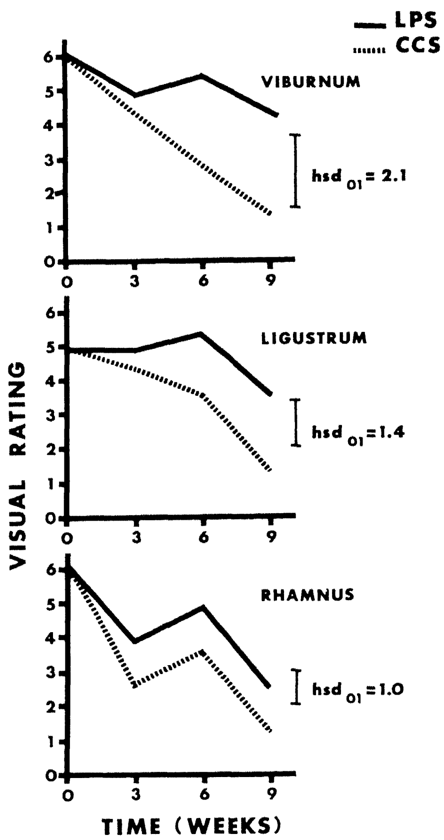

FIG. 4.—Visual evaluation of root quality of unrooted Compact European Cranberrybush, Regel Privet, and Tallhedge cuttings after 6 weeks in the propagation bed following either 3, 6, or 9 weeks in LPS or CCS.

The foliage and roots of unrooted Compact European Cranberrybush cuttings after 6 weeks in the propagation bed were of acceptable commercial quality from 3, 6, and 9-week LPS, while similar cuttings from CCS were acceptable only from the 3-week storage treatment Foliage and rooting characteristics of Regel Privet and tallhedge cuttings from 3 and 6-week LPS were of acceptable quality; however, only Regel Privet and tallhedge cuttings from 3-week CCS were of acceptable quality. Minor differences were observed with Compact European Cranberrybush cuttings from the 3-week storage treatment after 6 weeks in the propagation bed regardless of the storage system, while both Regel Privet and tallhedge cuttings did show some variation in quality between cuttings removed from the LPS and CCS systems (Fig. 5).

DISCUSSION

Treatment x week interactions were observed with nearly every parameter measured in this experiment (Figs. 1, 3, and 4). In general, quality of LPS cuttings declined gradually at each removal date, while CCS showed a more rapid decline in quality. The inference which can be drawn from this result is that if one wants to store cuttings for short periods (less than 3 weeks), either CCS or LPS will yield acceptable results, but if longer storage periods are required, LPS should be used.

From the experiments conducted, 6-week LPS of Regel Privet and tallhedge and 9-week LPS of Compact European Cranberrybush appear to yield an acceptable product after rooting (Figs. 3 and 4). Three-week CCS of all species yielded acceptable results after rooting, but the quality of material appeared lower than LPS material. Though Compact European Cranberrybush cuttings were termed unacceptable at removal after 9-week storage, the amount of new growth and the development of a root system after 42 days in the propagation bed yielded a cutting of acceptable quality.

Previous work with CCS has shown that some unrooted cuttings can be stored as long as 90 days and yield a commercially acceptable product (2). Most of the cuttings that have been stored appear to be composed of more lignified tissues or have a limited leaf area. It has been inferred that lignified tissue stores better than non-lignified (10); this appears to be true when noting that impatiens cuttings, a non-

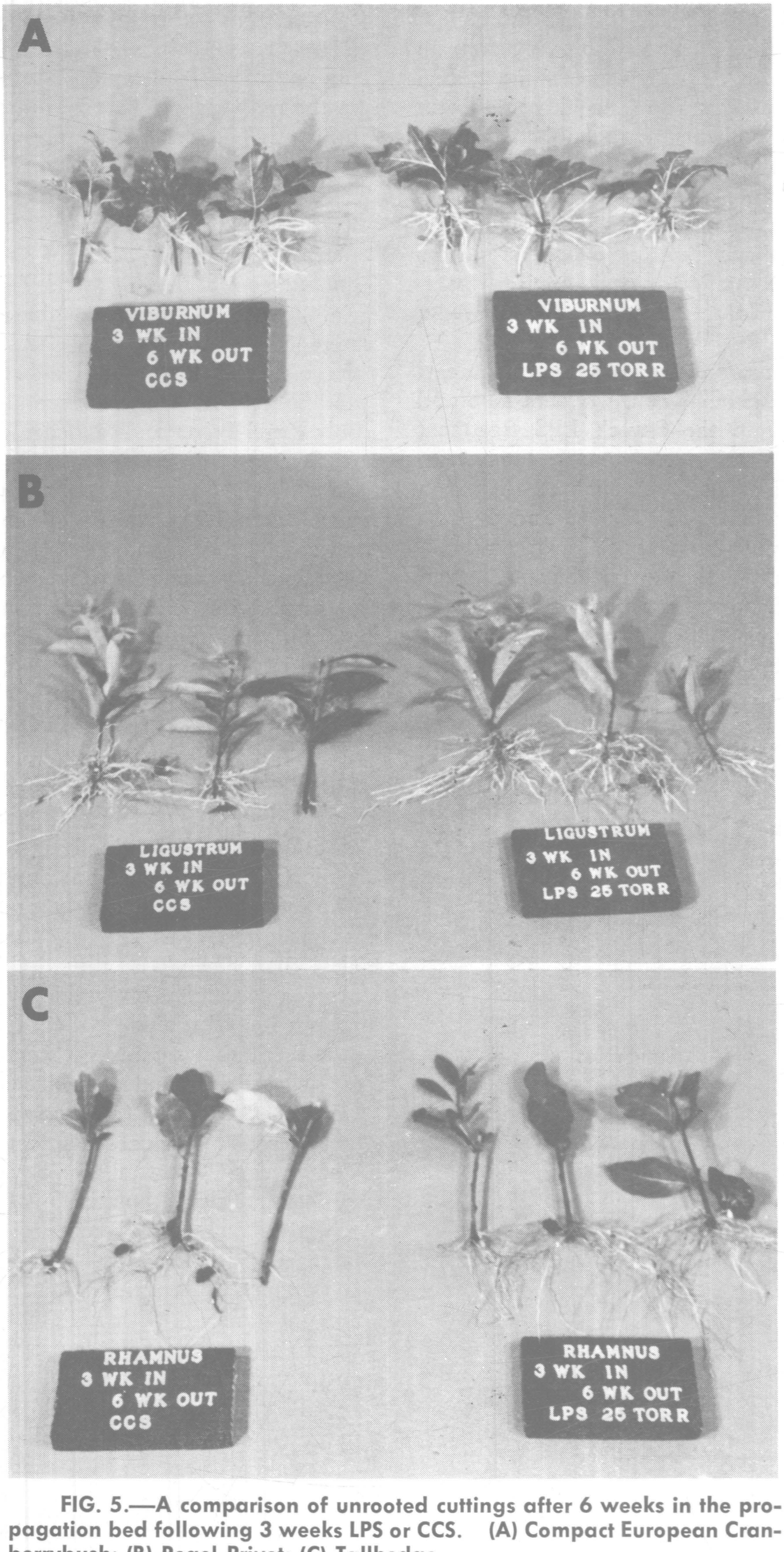

FIG. 5.—A comparison of unrooted cuttings after 6 weeks in the propagation bed following 3 weeks LPS or CCS. (A) Compact European Cranberrybush; (B) Regel Privet; (C) Tallhedge.

lignified cutting, can only be stored successfully for 14 days using CCS (13). With LPS, less lignified tissues can be stored successfully for periods up to 28 days (4, 8). One can infer that LPS extends the storage life of lignified tissues beyond periods achieved in CCS, which was the case in these experiments due to the soft nature of the cuttings used.

Cuttings from CCS often defoliated (Fig. 2), showed pathological invasion and an overall loss of color. No such symptoms were observed on LPS cuttings. Due to the low partial pressure of oxygen achieved with LPS (5, 7), growth of pathogens has been reduced (16). Since little pathogen growth was noted on LPS cuttings, it seems plausible to assume that the reduction of pathogen growth was due to LPS.

Defoliation of plant material is noted to be influenced by ethylene (1, 6) The concentrations of all gases in and out of plant materials (*e.g.*, ethylene) are proportionally reduced with the reduction in atmospheric pressure in the LPS system (5). Since defoliation occurred in CCS and was minimal in LPS, the reduced gas levels achieved in LPS may have reduced leaf drop. Since leaves might supply carbohydrates, auxins, and cofactors for rooting (9), a loss of leaves could reduce rooting and subsequent growth In comparing the LPS and CCS results (Figs. 3 and 4), one could infer that LPS cuttings maintaining a greater number of leaves in good condition when compared to CCS cuttings at removal from storage thus allowed the LPS cuttings to respond better during the rooting period.

Cuttings from CCS, when compared to those from LPS, displayed a greater degree of yellowing. The LPS system retards chlorophyll breakdown (7) which may have been related to the disorder seen in CCS cuttings. With geranium cuttings stored in LPS or CCS, similar results have been achieved (8). Before a definite answer to the yellowing problem can be fully explained, experiments need to be conducted evaluating controlled atmosphere storage (low oxygen tension at atmospheric pressure).

The advantages of LPS have been documented previously (3, 4, 5, 7, 8). Previous LPS work done with other rooted and unrooted crops has shown similar results to those cited in these experiments (3, 4, 8). More work is still needed in the area of cutting storage, but it appears that the LPS system, at this time, can be a valuable tool in extending the storage life of unrooted cuttings.

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Foliar Analysis Survey of Woody Ornamentals

ELTON M. SMITH[1]

INTRODUCTION

Soil and leaf analyses are standard procedures used to diagnose plant nutrient imbalances and to base fertilizer recommendations for many agronomic and horticultural crops. Leaf analysis has not been utilized extensively in ornamental horticulture because research data have been limited. The majority of the work with landscape plants has been confined to research with selected species such as holly (5), taxus (1, 7, 8, 9, 10), magnolia (6), rhododendron (4), viburnum (4, 10), hawthorn (2), pin oak (2), and honeylocust (2). Some research has been conducted with mineral levels in a number of species and cultivars of landscape plants, including 7 in Michigan (3), 12 in Canada (11), and 30 in Ohio (12).

The objective of this paper is to present foliar analysis values of a substantial number of woody ornamentals to serve as a benchmark for future research and as a guideline for leaf analysis recommendations. The data for 12 mineral elements have been gathered from a nursery survey, and foliar analysis reports from commercial producers and landscape nurserymen.

PART I—NURSERY SURVEY

To gather data from as many woody landscape species and cultivars as possible, a survey was conducted to sample foliage from healthy plants growing in commercial nurseries. The survey of 107 species and cultivars was conducted between 1968 and 1974 from plants in nurseries throughout Ohio.

Foliage samples were collected from the most recent fully expanded leaves of at least 10 plants per nursery, while terminal cuttings 2-3 inches in length were removed from a minimum of 50 narrowleaf evergreens. Samples were collected only during the months of July and August from healthy plants. Nitrogen was analyzed by the micro Kjeldahl process and the 11 other mineral elements were determined on a direct reading emission spectrograph.

Mean values of most mineral elements of deciduous plants were quite similar to those of the evergreens with the exception of Ca, Mg, and Zn (Table 1), which were all lower. Terminal growth of the narrowleaf evergreens was lower in Ca and Mg as expected since some of the growth was immature. The mineral element values of each of the plants are presented in the Appendix.

Values in this compilation of plants compare favorably with a similar study of 12 woody species in Ontario, Canada (11). In both studies, the N level of evergreens was lower than deciduous plants.

PART II—INDUSTRY SAMPLES

The plant analysis laboratory at the OARDC has been testing foliage of woody ornamentals since the mid-1960's. Growers, however, were not using the foliar analysis service as a production tool until the early 1970's.

Foliar mineral element values from 617 samples, representing 85 different species and cultivars of

[1]Professor of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

TABLE 1.—Average Foliar Mineral Element Values of 107 Deciduous and Evergreen Species and Cultivars of Woody Ornamentals from a Survey of Commercial Nurseries.

Plant Type	Number of Plants	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
		percent					ppm						
Deciduous	80	2.40	0.33	1.23	1.54	0.36	113	224	31	13	2.2	33	332
Evergreen	27	2.11	0.31	1.19	0.96	0.23	187	213	27	15	1.9	54	314

TABLE 2.—Average Foliar Mineral Element Values of 617 Samples Representing 85 Deciduous and Evergreen Species and Cultivars of Woody Ornamentals from Grower Samples Submitted for Analysis.

Plant Type	Number of Samples	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
		percent					ppm						
Deciduous	76	2.19	0.34	1.59	1.12	0.31	147	219	40	9	2.0	47	236
Evergreen	541	2.17	0.39	1.58	0.72	0.28	238	189	27	10	1.4	53	168

TABLE 3.—Average Foliar Mineral Element Values of 724 Samples of Deciduous and Evergreen Species and Cultivars of Woody Ornamentals from a Nursery Survey and Grower Samples Submitted for Analysis.

Plant Type	Number of Samples	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
		percent					ppm						
Deciduous	156	2.30	0.34	1.41	1.33	0.34	130	222	36	11	2.1	40	284
Evergreen	568	2.14	0.35	1.38	0.84	0.26	213	201	27	13	1.7	54	241
Average	724	2.22	0.35	1.40	1.09	0.30	172	212	32	12	1.9	47	263

woody ornamentals, have been selected from samples submitted to the laboratory between 1972 and 1976. The majority of these samples represented healthy plants in which producers were monitoring their fertilizer program. A considerable number, however, were from producers and landscapers submitting unhealthy foliage for diagnosis of mineral disorders. No attempt was made to differentiate these samples as the growth status on the forms was often incomplete or missing.

The data pooled from these industry samples, as seen in Table 2, indicates a close similarity of values, especially N, P, and K, between deciduous and evergreen plants. The Ca and B levels were higher in the deciduous plants than in the evergreens, while Zn was lower.

SUMMARY AND DISCUSSION

When the mineral element values are combined from each of the two parts of this report, it becomes apparent that the values from the 724 samples representing more than 150 species and cultivars are quite similar between deciduous and evergreen species as noted in Table 3. In all instances, Ca, Mg, and B were somewhat higher in deciduous foliage and Zn was slightly lower.

The significance of the similarity of mineral element values between deciduous and evergreen plants will be the simplification of diagnosing mineral element imbalance and making future fertilizer recommendations based cn foliar analysis.

Inasmuch as all plants in the survey and most plants from the industry samples were healthy and growing satisfactorily, it can be assumed that the values presented in Table 3 can be interpreted as sufficient for growth of a wide range of woody ornamentals. Further research remains to more critically define lower (deficient), optimum, and upper (excess) mineral element levels for woody ornamentals.

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APPENDIX—MINERAL ELEMENT VALUES OF WOODY ORNAMENTALS

DECIDUOUS TREES

	percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Acer nigrum	1.83	0.22	0.61	2.80	0.32	212	282	46	09	26	381	2.93
Acer platanoides 'Crimson King'	2.55	0.24	1.34	1.73	0.29	030	226	42	12	25	591	1.33
Acer platanoides 'Emerald Queen'	2.80	0.34	1.33	2.57	0.35	041	330	56	14	33	689	2.58
Acer rubrum 'Schlesinger'	2.60	0.42	1.23	1.39	0.57	020	683	31	18	45	600	4.39
Acer saccharinum	2.34	0.33	0.92	1.07	0.35	144	204	26	12	43	330	2.44
Acer saccharum	2.15	0.23	0.90	1.81	0.30	030	226	52	10	26	489	1.92
Amelanchier grandiflora	1.50	0.30	1.04	1.76	0.40	050	092	18	12	26	190	2.26
Betula nigra	1.48	0.30	1.62	1.51	0.21	029	107	38	10	23	111	0.96
Betula pendula	2.52	0.27	1.46	1.36	0.22	457	170	63	16	58	203	1.10
Carpinus betulus 'Fastigiata'	2.30	0.27	0.63	2.55	0.42	452	390	54	10	29	729	3.76
Cercidiphyllum japonicum	1.82	0.29	0.69	2.32	0.33	024	083	30	10	15	212	1.70
Cercis canadensis	3.80	0.32	1.24	1.32	0.31	022	120	19	09	23	146	1.27
Cornus florida	2.24	0.21	0.61	2.42	0.08	010	033	21	13	24	916	2.08
Crataegus 'Lavelle'	1.70	0.31	1.25	1.63	0.51	046	123	25	11	36	297	2.58
Crataegus phaenopyrum	1.48	0.21	1.05	1.38	0.33	075	158	14	14	23	546	1.14
Elaeagnus augustifolius	3.50	0.34	1.14	0.78	0.26	053	246	15	12	29	514	0.63
Eucommia ulmoides	1.90	0.30	1.04	1.14	0.37	047	144	32	08	28	177	1.79
Fagus grandifolia	2.35	0.23	0.68	1.03	0.34	275	222	47	10	38	577	1.92
Fraxinus americana	2.00	0.48	0.80	2.39	0.41	032	172	29	12	18	319	3.15
Fraxinus 'Marshall Seedless'	2.75	0.27	1.15	1.22	0.34	028	308	19	13	27	300	1.52
Ginkgo biloba	2.55	0.49	0.97	1.55	0.74	024	404	33	10	08	282	4.03
Gleditsia triacanthos 'Moraine'	3.40	0.52	1.76	1.16	0.27	024	122	23	14	36	081	1.39
Gleditsia triacanthos 'Skyline'	3.80	0.36	1.56	1.80	0.16	041	387	32	16	26	272	0.66
Gleditsia triacanthos 'Sunburst'	4.15	0.51	1.95	1.83	0.24	043	341	34	18	35	295	1.09
Gymnocladus dioicus	3.33	0.38	1.03	2.34	0.40	049	342	50	12	21	672	5.30
Liquidambar styraciflua	1.78	0.29	0.97	0.89	0.31	555	148	23	18	45	377	2.71
Liriodendron tulipifera	2.74	0.34	1.35	1.81	0.44	069	235	21	13	27	375	2.89
Magnolia loebneri 'Merrill'	3.30	0.30	1.11	1.97	0.51	428	285	45	12	35	511	4.63
Malus 'Royalty'	2.70	0.34	1.73	0.83	0.30	032	134	34	12	24	170	0.97
Malus 'Sargenti'	2.10	0.28	1.26	0.82	0.20	025	124	25	09	18	146	0.98
Ostrya virginiana	1.62	0.23	0.70	2.27	0.36	211	535	35	11	22	956	3.94
Platanus hybrida	2.85	0.48	1.43	1.29	0.56	097	570	26	19	36	242	4.82
Platanus hybrida 'Bloodgood'	1.79	0.28	0.76	1.81	0.55	064	129	28	13	23	260	4.32
Prunus serrulata 'Kwanzan'	2.42	0.30	1.13	1.41	0.55	143	167	40	15	25	165	2.57
Prunus 'Thundercloud'	2.20	0.29	2.55	1.15	0.40	028	181	34	11	23	387	1.09
Pyrus calleryana 'Bradford'	2.10	0.19	1.92	1.22	0.21	039	122	19	12	22	085	0.27
Quercus rubra maxima	3.15	0.30	0.96	1.01	0.33	454	595	36	11	34	498	1.39
Quercus shumardi	1.97	0.23	0.80	1.49	0.45	290	184	33	09	28	346	2.97
Quercus palustris 'Sovereign'	1.97	0.26	0.97	0.99	0.28	218	139	19	11	43	213	1.55
Sophora japonica	3.55	0.43	1.49	1.92	0.49	044	669	45	15	33	440	3.18
Sorbus aucuparia	3.04	0.35	1.56	1.78	0.44	227	245	17	12	21	222	1.68
Tilia cordata 'Chancellor'	2.30	0.29	1.30	2.46	0.45	218	212	49	10	28	424	3.23
Tilia cordata 'Greenspire'	3.20	0.37	1.40	1.90	0.47	088	588	40	14	30	484	3.79
Tilia tomentosa	2.44	0.32	0.91	3.07	0.61	094	160	56	13	29	435	6.59
Zelkova serrata	3.10	0.39	1.56	1.06	0.26	216	302	31	11	21	190	0.90

DECIDUOUS SHRUBS AND VINES

	percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Berberis atropurpurea	1.64	0.38	0.70	0.99	0.21	023	291	30	15	37	609	1.45
Campsis radicans	1.97	0.34	1.25	1.08	0.42	032	216	19	24	26	069	2.17
Chaenomeles lagenaria	2.60	0.26	1.03	1.90	0.36	069	163	36	16	41	223	0.95
Cornus alba 'Siberica'	2.60	0.62	1.10	2.23	0.36	013	075	34	10	33	064	1.77
Cornus racemosa	1.82	0.31	1.18	2.95	0.58	010	082	21	09	22	155	4.79
Cornus sericea 'Flaviramea'	2.18	0.60	1.39	1.98	0.33	011	072	30	10	26	080	1.43
Cotinus coggygria	2.50	0.34	1.08	1.22	0.25	010	177	27	11	23	266	1.05
Cotoneaster apiculata	3.90	0.36	1.13	1.08	0.17	137	202	30	14	43	247	0.65
Euonymus alatus 'Compacta'	2.40	0.21	1.24	1.65	0.10	073	304	28	12	34	288	0.69
Forsythia 'Arnold Dwarf'	1.51	0.28	1.43	0.47	0.36	042	101	14	15	29	089	2.32
Forsythia intermedia spectabilis	2.16	0.27	1.40	0.87	0.26	109	102	14	22	36	058	1.18
Hamamelis virginiana	2.25	0.25	0.59	1.22	0.25	082	154	25	10	22	215	1.65
Ligustrum amurensis	1.10	0.60	1.48	1.52	0.34	058	137	21	16	40	160	1.81
Lonicera japonica 'Halliana'	2.95	0.42	2.23	1.28	0.46	572	208	29	19	86	153	2.79
Lonicera zabel	2.67	0.42	1.51	1.99	0.55	010	116	42	12	36	169	3.59
Parthenocissus quinquifolia	2.77	0.68	2.44	1.87	0.31	459	257	22	07	43	180	1.74
Philadelphus virginalis	3.09	0.42	2.64	2.14	0.51	021	121	32	13	36	139	2.09
Potentilla 'Gold Drop'	2.21	0.45	1.26	0.76	0.29	076	186	24	13	37	228	1.84
Rhamnus frangula 'Columnaris'	3.25	0.34	1.47	1.19	0.41	096	274	26	11	34	350	1.63
Rhododendron 'Cascade'	2.22	0.25	1.06	0.88	0.56	103	233	29	16	48	384	2.66
Rhododendron mollis	1.86	0.20	0.63	1.00	0.30	119	137	28	13	31	263	1.32
Rhus aromatica	1.96	0.29	1.11	1.47	0.39	023	150	27	10	29	229	1.63
Rosa rugosa	2.27	0.70	1.30	2.12	0.43	027	152	63	12	31	204	3.76
Rosa wichuriana	1.79	0.23	0.80	1.76	0.46	198	285	58	09	34	521	4.32
Spiraea japonica alpina	2.24	0.26	1.55	0.92	0.33	312	461	35	21	61	828	3.68
Spiraea 'MacFarland'	1.78	0.38	1.10	0.43	0.20	059	147	19	10	33	168	1.37
Spiraea nipponica 'Snowmound'	2.41	0.34	1.10	0.99	0.36	043	102	25	13	27	075	2.07
Stephanandra incisa 'Crispa'	1.76	0.14	0.60	1.44	0.47	168	217	32	07	38	359	2.47
Syringa persica	2.75	0.26	1.07	0.94	0.28	028	115	16	15	36	164	0.81
Syringa vulgaris 'Edith Cavelle'	2.08	0.27	2.35	0.71	0.45	118	119	19	14	41	071	1.43
Viburnum lantana	2.10	0.25	0.91	1.43	0.41	023	215	29	11	34	424	1.42
Viburnum plicatum	1.54	0.27	1.34	0.84	0.33	063	123	29	11	28	172	1.08
Viburnum prunifolium	1.75	0.29	1.01	1.66	0.48	021	207	27	10	33	381	2.83
Viburnum rhytidophyllum	1.70	0.24	1.14	1.41	0.40	033	334	24	13	36	615	1.98
Weigela 'Vanicekii'	2.39	0.38	1.48	1.27	0.29	016	117	28	12	33	113	1.37

BROADLEAF EVERGREENS

	percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Euonymus fortunei 'Coloratus'	2.41	0.20	1.00	1.58	0.25	055	135	34	09	36	181	1.41
Euonymus fortunei vegetus	2.38	0.32	0.58	2.64	0.10	025	311	34	17	28	382	0.79
Hedera helix	2.64	0.33	2.49	0.48	0.15	059	389	26	26	50	951	0.90
Ilex crenata 'Convexa'	3.14	0.33	1.43	0.87	0.48	342	317	23	19	89	488	3.61
Ilex opaca	1.66	0.20	0.97	0.93	0.37	437	204	27	38	82	524	1.87
Leucothoe fontanesiana	1.76	0.30	0.64	4.12	0.12	016	085	43	19	35	1020	14.98
Pieris japonica	1.68	0.19	0.94	0.53	0.13	587	032	20	10	29	073	0.84
Pyracantha coccinea 'Lalandi'	2.76	0.42	1.16	1.40	0.30	028	124	35	15	54	102	1.66
Rhododendron 'Nova Zembla'	1.61	0.22	1.14	0.62	0.33	373	093	28	09	35	094	1.47
Rhododendron 'Roseum Elegans'	1.12	0.12	1.00	0.79	0.27	156	1053	29	08	35	347	1.45
Vinca minor	2.42	0.30	1.61	1.62	0.48	053	259	41	21	46	289	2.28
Yucca filamentosa	2.41	0.20	1.00	1.58	0.25	055	135	34	09	36	181	1.41

NARROWLEAF EVERGREENS

	percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
Chamaecyparis pisifera 'Cyanoviridis	2.38	0.56	1.49	1.26	0.30	359	147	28	08	33	137	1.89
Juniperus horizontalis 'Bar Harbor'	2.07	0.39	1.56	1.07	0.27	276	142	15	11	36	197	1.57
Juniperus chinensis 'Pfitzeriana Compacta'	2.26	0.44	1.09	1.62	0.21	147	142	21	16	43	081	1.82
Picea abies	1.80	0.31	0.76	0.46	0.10	038	128	17	09	33	158	0.95
Picea omorika	1.26	0.23	0.89	0.23	0.06	073	109	18	26	31	168	0.53
Picea pungens	2.10	0.21	0.61	0.24	0.08	022	105	15	08	24	124	0.37
Pinus mugo mugo	1.62	0.25	0.89	0.45	0.17	099	219	26	08	38	342	1.57
Pinus ponderosa	1.71	0.27	0.80	0.29	0.23	074	184	27	08	53	287	1.35
Pinus strobus	2.28	0.30	0.87	0.22	0.08	134	094	15	14	54	164	0.56
Pinus thunbergi	1.76	0.25	0.94	0.33	0.18	124	180	30	08	47	332	0.99
Taxus media 'Browni'	2.36	0.46	1.57	0.66	0.21	567	149	27	18	78	102	0.93
Taxus media 'Hicksii'	1.80	0.39	1.87	0.59	0.18	617	345	34	16	83	330	2.11
Thuja occidentalis pyramidalis	1.96	0.36	0.83	1.58	0.28	163	169	21	20	47	123	1.28
Thuja orientalis 'Aurea Nana'	1.89	0.46	1.53	0.81	0.39	068	163	27	09	31	188	1.33
Tsuga canadensis	3.00	0.46	1.35	0.40	0.15	208	113	21	12	36	619	1.10

Changes in Mulch and Soil Nitrate Levels Following Nitrogen Fertilization

ELTON M. SMITH, CYNTHIA D. MITCHELL, and JOSEPH RIMELSPACH[1]

INTRODUCTION

The practice of mulching ornamentals in landscape plantings has increased steadily over the years. Mulches serve many purposes, including the maintenance of more uniform soil moisture and temperature conditions and the reduction of weed seed germination. The greatest disadvantage of using organic mulches is the decreased growth caused by nitrogen depletion (1, 5, 7). Microorganisms responsible for decomposition compete with plant roots for available nitrogen when the C:N ratio is greater than 25:1 (3).

Among the more popular mulches are pine bark chips and pine needles in southern United States and shredded hardwood bark and wood chips in the north. Fresh hardwood bark may have a C:N ratio as high as 350:1 (1), although more commonly the ratio is in the vicinity of 100:1 (6). Most barks such as pine bark and shredded hardwood bark decompose more slowly than wood products such as wood chips or sawdust, and hence have lower nitrogen requirements (1). Ground corncobs have a reported C:N ratio of 122:1 (8). As a general rule, nitrogen deficiency may be avoided by the application of a nitrogenous fertilizer. Approximately 25 lb (1) to 30 lb (5) of nitrogen/ton of dry sawdust is required for decomposition.

This study was undertaken to determine how five common landscape mulches would influence soil nitrogen availability following nitrogen application and to ascertain carbon—nitrogen changes within the mulches.

MATERIALS AND METHODS

The study was conducted in a silty clay loam soil, with an average pH of 6.1, in a cleared field located in Milford Center, Ohio. The mulches were spread in plots 2' x 2' and uniformly 2" deep on Oct. 20, 1976. There were four replications of each plot of mulch in a random pattern. The mulches evaluated and their sources were: 1) ground corncob grits, marketed as Grit-O'Cobs Grade 1420 by The Andersons-Cob Division, Maumee, Ohio; 2) pine bark chips sold as Pine Bark Micronuggets by Greenlife Products Company, West Point, Va.; 3) hardwood bark in commerce as Shredded Hardwood Bark Mulch from Greenlife Products Co., West Point, Va.; 4) pine needles, collected and shipped from Atlanta, Ga.; and 5) fresh wood chips, chipped from primarily mixed hardwoods in line clearance work in Columbus, Ohio.

The liquid fertilizer was applied over the surface on Oct. 26, 1976, at the rate of 2.0 lb actual nitrogen/1000 sq ft.

The mulches and soil directly under the mulches were sampled in late November, December, February, and March. The soil was analyzed for nitrate nitrogen, the mulches for total carbon (2) and total nitrogen (4).

RESULTS AND DISCUSSION

The average soil nitrate level of all plots as shown in Table 1 at the time of nitrogen application was 18 ppm. This value increased 70% to an average of 31 ppm 1 month following fertilizer application and that level was maintained for 1 additional month. No samples were taken in January, 3 months following application, due to frozen soil conditions. However, by the end of the 4th month, average soil nitrogen levels dropped to close to the original level before the fertilizer application. The soil nitrate levels further decreased to one-half the original level at the end of the 5th month. This pattern suggests that the 2.0 lb

[1]Professor and former Agricultural Technician, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center, and Horticulturist, Chem Lawn Corp., Columbus, Ohio.

TABLE 1.—Soil Nitrate Levels Under Five Common Mulches Prior to and at Monthly Intervals Following Fertilization at 2.0 lb N/1000 sq ft in October.

	Nitrates ppm						
	Unmulched Soil	Corncobs	Utility Chips	Hardwood Bark	Pine Needles	Pine Bark	Average
October*	21.0	13.0	10.5	12.5	28.8	20.8	17.8
November	46.0	18.5	32.0	18.5	32.8	36.8	30.8
December	38.3	16.5	42.8	23.0	35.3	32.8	31.4
February	19.5	5.5	18.0	19.5	30.5	23.3	19.4
March	9.0	5.5	8.0	7.8	12.3	12.8	9.2

*All October samples taken prior to fertilizing.

TABLE 2.—Percent Carbon, Nitrogen and C:N Ratio of Five Mulches Prior to and at Periodic Intervals Following Fertilization at 2.0 lb N/1000 sq ft.

Mulch Treatment	Prior to Fertilization Oct. C	N	C:N	Following Fertilization Nov. C	N	C:N	Dec. C	N	C:N	Feb. C	N	C:N	March C	N	C:N
Fresh ground corncobs	44.2	0.24	184	39.9	0.34	120	41.2	0.30	144	43.9	0.33	138	38.2	0.25	155
Fresh utility wood chips	44.8	0.84	53	33.2	0.67	60	41.4	0.75	56	40.8	0.82	50	42.4	0.48	89
Shredded hardwood bark	44.1	0.28	153	40.2	0.31	130	38.5	0.40	96	40.6	0.40	107	35 8	0 33	110
Pine needles	49.7	0.60	83	47.9	0.76	63	48.9	0.87	56	49.2	0 63	79	47.3	0 71	68
Pine bark chips	48.9	0.20	245	41.6	0.25	170	44 8	0.32	143	47.3	0.30	157	44.6	0.25	184
Average	46.3	0.43	145	40.6	0.47	109	42.9	0.53	99	44.4	0.50	106	41.7	0.40	121

actual nitrogen rate increased soil nitrate levels for 2-3 months before decreasing to initial levels.

Examination of soil nitrate levels of unmulched treatments suggests the same pattern as the mulched plots, with a slightly larger increase of 120% in nitrate levels following fertilization after the 1st month. The difference in soil nitrate levels between mulched and unmulched plots was expected due to the utilization of the nitrogen by the soil microorganisms as reported by several researchers (1, 5, 7).

Interestingly, the largest increase in soil nitrate levels in the first 2 months was not in the bare soil plots but in the utility wood chips treatment. The most likely explanation is the high leaf content of summer utility wood chips which added to the nitrate level as they decomposed. The soil nitrate levels in this plot, however, decreased rapidly between the 2nd and 4th months to reach the same level, 18 ppm, as the soil and the average of all the mulches.

The average soil nitrate level considered satisfactory for adequate growth of ornamentals is 30-40 ppm. Thus, two mulches, corncobs and hardwood bark, appeared to "tie-up" the applied nitrogen and the soil nitrate levels did not reach the desired 30-40 ppm range during the first 2 months following application. From this study, more nitrogen will be needed per application to raise soil nitrate levels to desirable levels for plant growth if corncobs or hardwood bark are the mulching materials, especially if the plants are located on low nitrate soils.

Generally, the C:N ratio of most of the mulches decreased for 2 months following nitrogen application as shown in Table 2. The C:N ratio decreased as a result of the nitrogen increase and carbohydrate decomposition. The C:N ratio by the end of March, however, increased from December levels in all mulches as the nitrogen content decreased to original levels of 0.43% in October to 0.40% in March. The C:N ratios on the average were not as high in March (121:1) as October (145:1) because the total carbon level decreased from 46% to 42%.

The nitrogen content of the freshly chipped utility wood chips was the highest of all initial mulch treatments at 0.84% and thus the C:N ratio was lowest at 53:1. The nitrogen content of the wood chips decreased to below original levels by March from 0.84 to 0.48% and the C:N ratio increased to 89:1. This was the only mulch to follow this pattern, due most likely to the high initial leaf nitrogen content.

The pine needle mulch had an initial low C:N ratio due to the fact that the dried needles were higher in nitrogen at 0.60% than the pine bark at 0.20%, hardwood bark at 0.28%, and corncobs at 0.24%.

As mulches decompose with time, the carbon levels will decrease as will the C:N ratio, and it is expected that a smaller amount of future nitrogen fertilizer will be "tied up" in the mulch and more will be available to the crop in question. Further research is needed to evaluate growth response of woody ornamentals to varying nitrogen treatments and mulch applications over a longer time period.

SUMMARY

The objectives of this study were to determine how several landscape mulches influenced soil nitrogen availability following nitrogen application at 2.0 lb N/1000 sq ft and to observe carbon—nitrogen changes within the mulches. Soil nitrogen levels increased for 2 months before decreasing to original levels after 4 months following fertilizer application. Ground corncobs and shredded hardwood bark appeared to "tie-up" the applied nitrogen to a greater extent than pine needles, pine bark chips, and utility wood chips. The C:N ratio of most mulches decreased from an average of 145:1 prior to fertilizing to 99:1 after 2 months, before returning to 121:1 or

within 15% of their original levels by March. The nitrogen levels of the mulches were generally equivalent in March with October readings, but total carbon levels decreased from 46 to 42%. The highest mulch nitrogen level and lowest C:N ratio were observed with fresh utility wood chips.

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Fertilizing Trees in the Landscape: A 6-Year Evaluation

ELTON M. SMITH[1]

INTRODUCTION

Trees moved into a landscape planting are often located in less than ideal soil conditions where soils may be: 1) thoroughly compacted from construction equipment or foot traffic, and 2) poorly drained due to the inherent nature of the soil. In these conditions, trees, if they do survive, are slow to become established and may grow quite slowly. As a result, these trees are more susceptible to pest problems (1) and winter injury. Many trees which died or were injured during the winter of 1976-77 entered the dormant season in an unhealthy condition and were affected by the extreme low temperatures.

Historically, fertilizer recommendations for trees have been based on caliper of the trunk, but more recently the basis has changed to branch spread or surface area (2, 3). Fertilizer and particularly nitrogen studies and recommendations indicate optimum tree growth will vary from 2-3 lb N/1,000 sq ft/yr (4, 5, 8) to 6 lb N/1,000 sq ft/yr (1, 2, 3) in average to good soil conditions. Studies have shown that tree growth is more directly related to fertilizer rate than to differences in fertilizer placement (1, 6).

The purpose of this study was to evaluate the effects of four nitrogen levels on the growth of three genera of trees located in poor soils, typical of those in many home landscapes.

[1]Professor, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

MATERIALS AND METHODS

This investigation was conducted in the USDA Nursery Crops Research Nursery in Delaware, Ohio. The soils were poorly drained Blount and Morley silt and Pewamo silty clay loam with a pH of 6.9.

The tree species, planted as branched whips in April 1969, included *Tilia cordata* 'Select'—Improved Littleleaf Linden; *Malus* 'Snowdrift'—Snowdrift Flowering Crabapple; and *Acer saccharum* 'Monumentale'—Sentry Sugar Maple. The trees were grown in sod culture, mowed and pruned as needed.

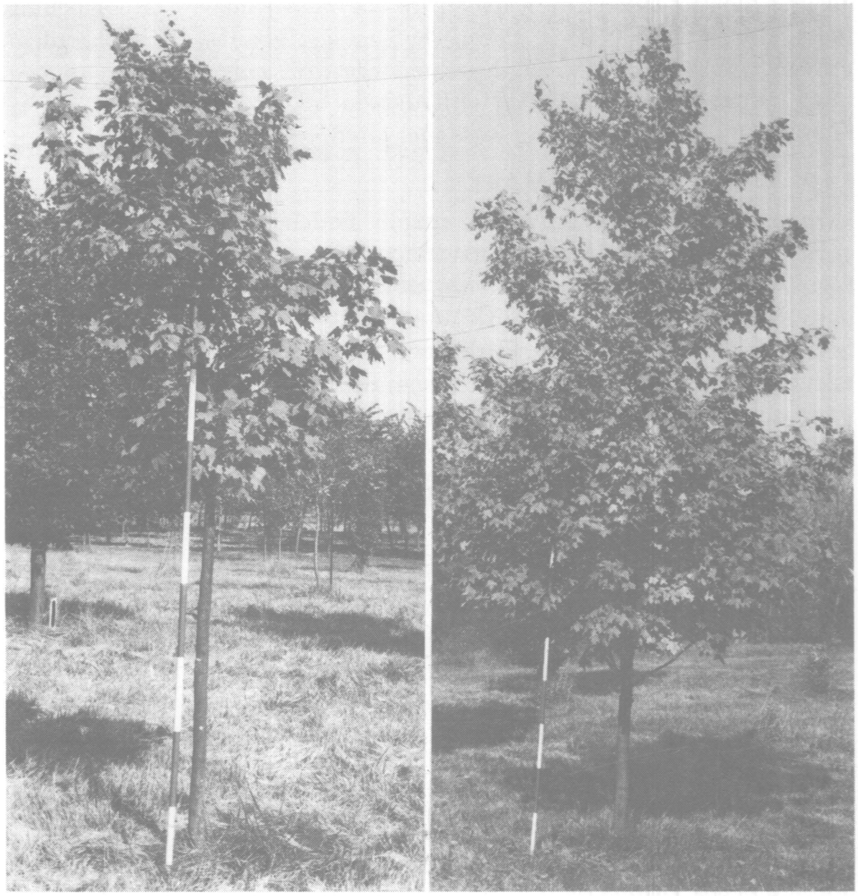
All trees received 6 lb of actual phosphorus and potassium per 1,000 sq ft in May 1971 and again in April 1974. The nitrogen, in the form of ammonium nitrate, was applied at the same time at either 0, 3, 6, or 9 lb N/1,000 sq ft. One-half of the treated trees received nitrogen as a surface application while the remainder were treated via a drill hole application. The 20 holes per tree, drilled with a 2" power auger 12" deep, were spaced in two concentric rings within a 100 sq ft area around each tree.

In the drill hole treatments, the fertilizer was mixed with calcined clay marketed as Sta-red-bits. One treatment consisted of a drill hole treatment filled with calcined clay without fertilizer to evaluate the effects from aeration alone.

The study was conducted utilizing a randomized block design with three trees per treatment and four

Flowering crabapple: left—check, right—6.0 lb N every 3 years.

Sugar maple: left—check, right—6.0 lb N every 3 years.



replications. Caliper measurements 1 foot from the ground were taken on Sept. 16, 1976.

RESULTS AND DISCUSSION

Most all fertilizer treatments plus the linden and crabapple treated with holes and filled with calcined clay without fertilizer were significantly larger in caliper than control trees without nitrogen (Table 1). There was almost no difference in growth of trees between those treated on the surface and those with drill hole applications.

The greatest caliper growth, on the average, of all three plant species in the drill hole treatment was the 6 lb N rate. Although the overall average of the 9 lb N rate was slightly higher in the surface treatment, in no cases were the differences significant. Thus, the 6 lb N treatment every 3 years over a 6-year period resulted in optimum caliper growth.

On the average, the holes only treatment filled with calcined clay resulted in a 0.8-inch increase in trunk caliper vs. unfertilized trees. This increase is most likely a direct result of increasing aeration

TABLE 1.—Effects of Fertilizer Treatments on Caliper Growth of Trees Grown in Soils Typical of Landscape Situations.

Treatment	Linden	Crabapple	Maple	Average
Control, no holes, no N	3.03 a*	3.40 a	3.38 a	3.27
Holes plus calcined clay	4.33 b	4.30 b	3.50 ab	4.04
3 lb N drill hole	4.58 bc	4.35 b	4.00 cd	4.31
6 lb N drill hole	4.55 bc	4.83 cd	4.50 e	4.63
9 lb N drill hole	4.80 cd	4.85 cd	3.95 bcd	4.53
3 lb N surface	4.78 bcd	4.50 bc	3.53 ab	4.27
6 lb N surface	4.90 cd	5.13 d	3.88 bc	4.64
9 lb N surface	5.08 d	4.85 cd	4.35 dc	4.76

*Letters followed by dissimilar letters within columns are significantly different at the 5% level.

around the root system. In five of the six treatments involving the 3 lb N rate, there were no significant growth differences between those and the drill hole treatment with calcined clay, although in all treatments slight caliper increases were measured.

SUMMARY

In summary, the growth of maple, linden, and crabapple was not affected by placement of fertilizer. Significant growth increases were noted from drill hole treatments without fertilizer, suggesting a direct benefit from aeration in poorly drained soils. Nearly all nitrogen treatments resulted in significant caliper increases, with the most effective being the 6 lb N/ 1,000 sq ft rate every 3 years.

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Growth of Container-Grown Ornamentals in Hardwood Bark as Influenced by Nitrogen Source and Rate During Composting

SUSAN F. STERRETT and THOMAS A. FRETZ[1]

INTRODUCTION

Peatmoss is widely used as an ingredient in the media for container-grown ornamentals, although increasing cost and decreasing availability have stimulated the search for more readily available substitutes. In the southern United States, hammer-milled softwood (pine) bark has been successfully substituted for peatmoss (18). Hardwood bark, a by-product of the paper and veneer industry, has also been used as a media ingredient in the production of container-grown ornamentals, but with varying degrees of success (3, 6, 10, 11, 19, 21).

Due to recent anti-pollution legislation, the disposal of hardwood bark by burning is now prohibited. The utilization of this inexpensive, locally available source of organic material could not only lessen the disposal problem, but would make use of a former waste product.

In general, hardwood bark used in the media of container-grown woody ornamentals has proven to be well-drained and well-aerated, has excellent water holding capacity, is light in weight, and has an ion exchange capacity which increases with age, exceeding that of peat (4, 12, 15). In addition, these hardwood bark amended media have exhibited a lower incidence of root rotting fungi and an increased suppression of nematodes (17).

While the advantages are many, the greatest disadvantage of using fresh hardwood bark in the growing medium is the decreased growth which results from nitrogen depletion (1, 6, 10, 11, 14, 21). Microorganisms responsible for decomposition compete with plants for available nitrogen when the C:N ratio is greater than 25:1 (5). Fresh hardwood bark may have a C:N ratio as high as 350:1 (1).

Lunt and Clark (15) noted that the decrease in the fresh weight of herbaceous plants grown in hardwood bark chips could be overcome by the addition of nitrogen. In the production of container-grown woody ornamental crops, the liquid fertility programs used with peat or softwood bark-amended media are not adequate with hardwood bark-amended media (10, 21). A high nitrogen fertilizer must be incorporated to offset the requirements of decomposition in order for the C:N ratio to be adjusted to a more favorable level.

[1]Former Graduate Research Associate and Associate Professor, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

In early experiments, the nitrogen depletion problem was overcome by the addition of slow release nitrogen to the media, followed by a constant liquid fertility program of 20-20-20 at the rate of 200 ppm (10). The present procedure involves the addition of 2% N (2 lb N/yd^3) prior to composting to offset the nitrogen requirements for the decomposition of the bark. Following composting, a fertility program of 250 ppm N at each irrigation was needed to supply the crop requirements (12).

Gartner (9) noted that the best source of nitrogen for composting was ammonium nitrate, while urea and straight ammonium nitrogen sources resulted in inferior growth. The pH of the bark decreased with ammoniacal sources of nitrogen, while it increased when nitrate-nitrogen sources were used (12). Ammonium sulfate as a nitrogen source was noted to cause a delay in nitrification and an accumulation of NH_4^+ that was detrimental to plant growth (13).

Due to the oil embargo during the spring of 1974, nitrogen fertilizers were in short supply in many areas of the United States, forcing producers of container-grown woody ornamentals to utilize whatever nitrogen sources which were available to compost hardwood bark. As a result, this study was initiated to investigate the use of three nitrogen sources on the C:N ratio and pH of bark-amended media and foliar nutrient levels, and subsequent growth of cotoneaster.

MATERIALS AND METHODS

Ammonium nitrate, $Ca(NO_3)_2$ or $(NH_4)_2SO_4$, was uniformly mixed into the fresh hardwood bark at rates of 0, 1.5, or 3.0 lb actual N per cubic yd. In all treatments, 5 lb of superphosphate, 1 lb of $FeSO_4$, and 1 lb of elemental S were added per cubic yd of bark. For each treatment, 205 lb of hardwood bark at 44.9% moisture were placed in a 55 gal barrel following treatment with one of the above nitrogen sources. Tap water was added to obtain 68% moisture. The barrels were then placed in a growth chamber maintained at 47.5° ± 1° C (120° F) for the 6-week composting period. Temperature of the media in the barrels was monitored and remained 3-4° C higher than the ambient chamber temperature during the first 30 days of composting. During the composting period, the bark was removed from each barrel and thoroughly mixed on a weekly basis to increase aeration and then returned to the heated chamber. After each turning, the barrels were weighed and water added to reestablish the moisture level at 68%.

During the composting period, four sets of samples were obtained for C:N determinations, pH and soluble salts analysis. At the completion of the composting period, a 2 bark:1 sand and a 1 bark:1 sand:1 peat medium were prepared for each nitrogen treatment. To adjust for low pH values (4.1) in the 1:1:1 medium, 90 g of $CaCO_3$ were added per ft^3, raising the pH to a more acceptable 5.5. The pH of the 2:1 medium needed no adjusting; however, 90 g of $CaSO_4$ were added per ft^3 to provide an equivalent quantity of Ca.

Uniform rooted cuttings of Royal Beauty Cotoneaster (*Cotoneaster dammeri* Schmeid. 'Royal Beauty') and Andorra Juniper (*Juniperus horizontalis* Moench. 'Plumosa') were planted in 1-gal nursery containers on May 1, 1975, at The Ohio State University nursery. A fertility program consisted of a single application of Osmocote, 18-6-12, at the rate of 1 tablespoon (17.6 g) per container at the initiation of the experiment. Peters 20-20-20 soluble fertilizer at the rate of 150 ppm was applied with every watering through the overhead irrigation system. Routine fungicide and insecticide applications were made as often as necessary, in accordance with standard nursery practices.

Monthly samples of the media were obtained for pH and soluble salts determinations. All pH and soluble salts determinations were made using a 1:2 medium to distilled water dilution. On Sept. 20, 1975, a growth index of both plant species was calculated as follows:

$$\text{Growth Index} = \frac{\text{plant height (cm)} + \text{plant width (cm)}}{2}$$

In addition, one plant of each replicate was harvested to obtain dry weight, and mature tip growth was removed from the remaining five plants within each replicate for foliar analysis.

Tissue for analysis was placed in a drying oven at 70° C for 2 days and ground in a Wiley mill to pass a 20-mesh screen. One-gram samples were dry ashed in a muffle furnace at 500° C for 4 hours and brought up to a volume of 50 ml with double distilled water (8). The Vanadate-Molybdate-Yellow procedure was used to determine P, using a B & L Spectrometer 20 Colorimeter at a wavelength of 420 nm (8). A Varian Techtron Model 1200 Atomic Absorption Spectrophotometer was used to determine K, Mg, Ca, Mn, and Fe. Calcium and Mg were determined by flame emission spectrophotometry at wavelengths of 422.7 and 766.5 nm, resp. K, Mn, and Fe were analyzed by atomic absorption at wavelengths of 202.5, 279.5 and 372.0 nm, resp. Foliar nitrogen was determined by the Micro-Kjeldahl method (16).

The C:N ratio of the hardwood bark used in the growing media was determined by using the Micro-Kjeldahl procedure of Bremmer (7) for nitrogen and the combustion procedure for total C (2).

The statistical design employed a randomized 2x3x3 factorial design with replications of six plants each. Where significant, differences between means were separated using Duncan's Multiple Range Test at the 5% level.

RESULTS AND DISCUSSION

The C:N ratio of the fresh bark used in this study was approximately 95:1. While the C:N ratio of the bark fluctuated during the composting period, the addition of 1.5 or 3.0 lb actual N/cubic yd appreciably lowered the C:N ratio. By the end of the growing season, the C:N ratio of the hardwood bark was similar at all N levels regardless of the nitrogen source (Table 1). This should not be construed, however, to indicate that composting without an N source is acceptable. Plants grown in the media prepared from the bark composted with the 0 nitrogen rate were smaller, as evidenced by a reduction in the dry weight of both roots and shoots (Table 2). Since the C:N ratio of the bark was still approximately 35:1 at the completion of the study, presumably equilibrium had not been obtained.

No significant differences were noted in the nutritional levels of the fresh bark prior to the initiation

TABLE 1.—Changes in the C:N Ratio of Hardwood Bark During Composting and at the Completion of the Experimental Period.

Nitrogen Level lb/cubic yd	C:N Ratio* Days of Composting 0	7	16	23	36	End of Growth Period
0	95:1	78:1	85:1	87:1	86:1	33:1
1.5		54:1	67:1	61:1	68:1	37:1
3.0		52:1	60:1	46:1	65:1	35:1

*All values are the means of three replications.

TABLE 2.—Growth Index, Dry Weight of Roots and Shoots, and Leaf N of 'Royal Beauty' Cotoneaster and 'Andorra' Juniper as Influenced by the Level of Nitrogen Added Prior to Composting.

Nitrogen Level lb/cubic yd	Growth Index (cm)	Dry Wgt Shoots (g)	Dry Wgt Roots (g)	N (%)
		Royal Beauty Cotoneaster		
0	28.2a*	18.6 a	2.7 a	2.88a
1.5	30.2b	24.4 b	3.4 b	2.83ab
3.0	30.5c	24.4 b	3.6 b	2.75b
		Andorra Juniper		
0	10.2a	4.25a	1.20a	2.59a
1.5	10.0a	4.11a	1.00a	2.53ab
3.0	10.5a	4.57a	1.31a	2.46b

*Means within columns with different letters are significantly different at the 5 % level.

of the composting treatments (Table 3). While the chemical composition of the fresh bark was relatively stable, with the $Ca(NO_3)_2$ treatments, lower levels of K, Mg, and Fe were present after 6 weeks of composting when compared to the other N sources employed in this study (Table 3). However, the elemental composition of the bark at the completion of the growing season was not significantly different between nitrogen sources (Table 3).

The pH of the fresh bark prior to the addition of the compost treatments was 5.8. By the end of the composting period, the pH was lower in the $(NH_4)_2SO_4$ and highest in the $Ca(NO_3)_2$ treatments than those treatments not receiving nitrogen during composting (Figure 1). With each of the nitrogen sources, the 1.5 lb rate had less of an effect on the final pH than the 3.0 lb rate.

During the first month of the growing season, the pH of both the 2:1 and the 1:1:1 media increased, only to be followed by a continual decline in pH for the remainder of the growing season. At the com-

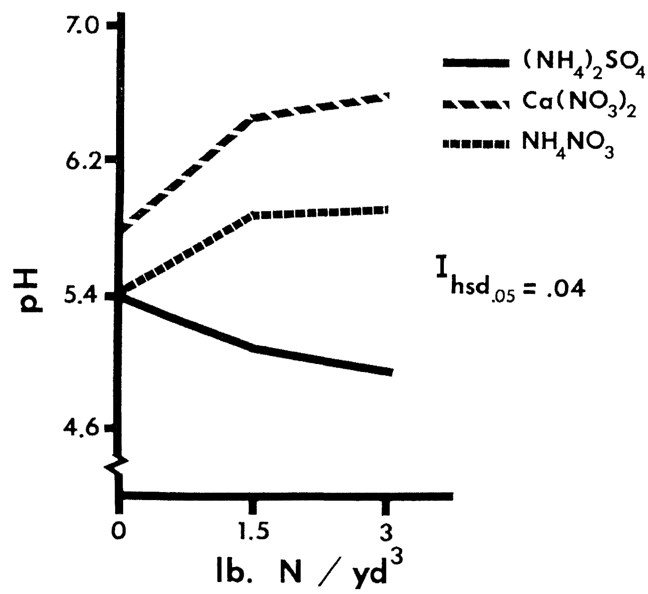

FIG. 1.—Hardwood bark pH at the completion of the 6-week composting period.

TABLE 3.—Changes in the Mineral Composition of Hardwood Bark when Fresh, when Composted, and at the Completion of the Growing Period.

Nitrogen Source	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)
			Fresh Bark			
$(NH_4)_2SO_4$	0.04a*	0.22a	2.50a	0.078a	1576a	385a
$Ca(NO_3)_2$	0.04a	0.21a	2.54a	0.076a	1740a	359a
NH_4NO_3	0.04a	0.21a	2.71a	0.076a	1669a	384a
			Composted Bark			
$(NH_4)_2SO_4$	0.09a	0.16b	3.01a	0.095b	5598b	350b
$Ca(NO_3)_2$	0.08a	0.13a	3.13a	0.065a	4141a	285a
NH_4NO_3	0.09a	0.15ab	3.27a	0.078b	5449a	348b
			Composted Bark at Completion of Growth Season			
$(NH_4)_2SO_4$	0.12a	0.13a	2.78a	0.052a	6860a	162a
$Ca(NO_3)_2$	0.12a	0.15a	2.59a	0.052a	6274a	248a
NH_4NO_3	0.12a	0.13a	2.74a	0.049a	7091a	223b

*Means within columns with different letters are significantly different at the 5 % level.

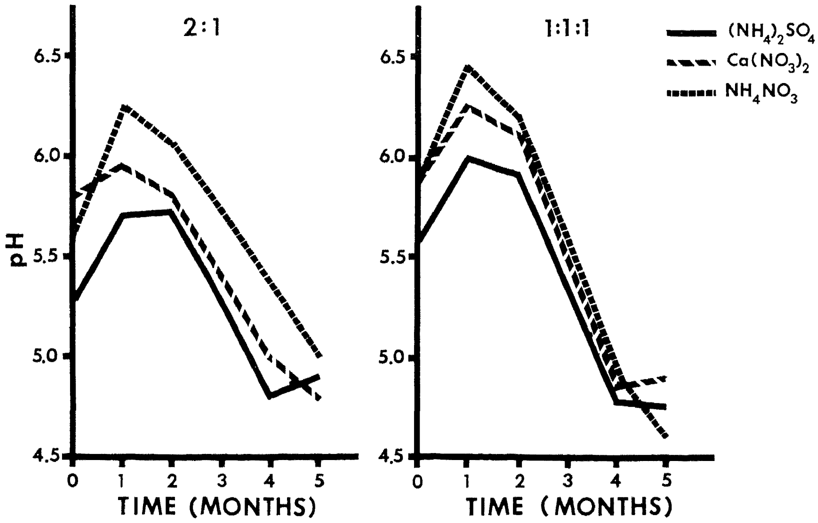

FIG. 2.—Hardwood bark pH during the growth season as influenced by the nitrogen source used during composting. Left: 2 bark:1 sand, right: 1 bark:1 sand:1 peat.

pletion of the study, the pH of all treatments ranged from 4.6 to 5.0 (Figure 2).

Since $(NH_4)_2SO_4$ is acid in reaction, NH_4NO_3 neutral, and $Ca(CO_3)_2$ basic, the change in the pH at the completion of the composting period was expected. The fact that the NH_4NO_3 treated media consistently exhibited a higher pH during the growing season is unexplainable at this time. It might be noted that the 20-20-20 soluble fertilizer used in the liquid fertility program was acid in reaction, and might account for part of the decline in pH. In addition, the $FeSO_4$ and elemental S used in the compost treatments in conjunction with the fertility program may have over-compensated for the natural tendency of the pH of the hardwood bark to increase with age (9, 12), particularly with the use of alkaline irrigation water.

The rate of nitrogen, regardless of source, added to the hardwood bark during composting significantly increased the growth index and the dry weight of the roots and shoots of the Royal Beauty Cotoneasters; however, it had no effect on the Andorra Junipers. With both species, there was a general decrease in the level of nitrogen in the leaf tissue as the rate of nitrogen added in the original composting treatments increased (Table 2). Differences in the growth indices and the dry weight for both roots and shoots for the Royal Beauty Cotoneaster for the various nitrogen composting treatments appear quite small; it should be noted that these are quite large when viewed as a percentage increase over the 0 nitrogen level. With the cotoneaster, the growth index increased 7.1% and 8.6% over the 0 nitrogen level with the addition of 1.5 and 3.0 lb/cubic yd of nitrogen. Similarly, this is reflected to an even greater degree in the dry weight of the shoot tissue, which increased 31% over the 0 nitrogen level as a result of the increased nitrogen level used during composting. Root dry weights increased 26 and 33% when compared to the 0 nitrogen level used during composting.

TABLE 4.—Elemental Composition of 'Royal Beauty' Cotoneaster and 'Andorra' Juniper Leaf Tissues as Influenced by Nitrogen Source Added to Hardwood Bark Prior to Composting.

	Leaf Tissue Composition						
N Source	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Mn (%)
				Royal Beauty Cotoneaster			
$(NH_4)_2SO_4$	2.84a*	0.34a	2.14b	1.11a	0.28a	234a	198a
$Ca(NO_3)_2$	2.82a	0.34a	1.99a	1.07a	0.27a	224a	256b
NH_4NO_3	2.79a	0.33a	2.04a	1.10a	0.27a	226a	200a
				Andorra Juniper			
$(NH_4)_2SO_4$	2.51a	0.27a	1.70a	0.81a	0.17a	103a	381a
$Ca(NO_3)_2$	2.53a	0.27a	1.71a	0.84a	0.17a	114a	487ab
NH_4NO_3	2.54a	0.28a	1.60a	0.89a	0.17a	92a	531c

*Means within columns with different letters are significantly different at the 5% level.

In general, the composition of the leaf tissue of the cotoneaster, with the exception of K and Mn, was not significantly influcnced by the source of nitrogen added prior to composting (Table 4). The levels of N, P, K, Mg, Ca, and Fe in the Andorra Junipers were not significantly influenced by the nitrogen source or rate applied prior to composting. Less Mn was noted in the plant tissues where plants were grown in media previously composted with $(NH_4)_2SO_4$ than with the other two nitrogen sources (Table 4).

While the nutrient levels within the leaf tissues of the cotoneasters and junipers varied slightly among treatments, all levels were within the acceptable range set for woody ornamentals except Mg (20). The increased growth generally noted as a a result of additional nitrogen during composting emphasizes the need to narrow the C:N ratio of the bark medium prior to using it as a medium for plant production. Since the C:N ratio of the hardwood bark at the end of the growing season was approximately 35:1, an adequate fertility program must be maintained throughout the growing season in order to supply the nutritional requirements of plants growing in a hardwood bark-amended medium. This study indicates that under optimum growth conditions, the nitrogen source added prior to composting did not greatly influence the growth or composition of the Andorra Juniper or Royal Beauty Cotoneaster plants, but nitrogen rate had a significant effect.

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Yellow Nutsedge Control in Container-Grown Nursery Stock with Bentazon

THOMAS A. FRETZ and WENDY J. SHEPPARD[1]

INTRODUCTION

Much of the previous herbicide research on container-grown ornamental crops has dealt with the preemergent control of weeds (1, 2, 4, 5). At the present time, no satisfactory postemergent herbicides are available to control weed growth in container nursery stock without causing excessive phytotoxicity. Under commercial nursery conditions, weeds may compete severely with container-grown nursery crops (3) and removal is accomplished via costly manual labor.

One herbicide, bentazon (Basagran), is available for postemergent control of broad-leaved weeds in soybeans and turf. In particular, bentazon gives outstanding postemergent control of yellow nutsedge *(Cyperus esculentus)* in turf. Since yellow nutsedge is a problem in the nursery industry, the authors established this study to evaluate the use of bentazon for the postemergent control of yellow nutsedge in container-grown ornamental plants.

MATERIALS AND METHODS

This study was conducted in the container nursery area at The Ohio State University to evaluate the use of bentazon (3-isopropyl-1H-2,1,3-benzothiadiazin (4)-3H-one 2,2dioxide) to control yellow nutsedge in container-grown nursery stock. Uniform cuttings of Royal Beauty Cotoneaster *(Cotoneaster dammeri* 'Royal Beauty'), Regel Privet *(Ligustrum obtusifolium* 'Regelianum'), Blue Mist Spirea *(Caryopteris* x *clandonensis* 'Blue Mist'), and Red Osier Dogwood *(Cornus sericea)* were planted in 1-gallon plastic nursery containers on June 6, 1977, in a medium of equal parts of sand, peatmoss, and milled hardwood bark. At the same time, 1-year-old liners of Andorra Juniper *(Juniperus horizontalis* 'Plumosa') were planted in 2-gallon plastic nursery containers in the same medium. Following potting, three yellow nutsedge tubers were planted in each nursery container at a depth of approximately 3½ inches. By June 5, 1977, the yellow nutsedge plants were approximately 4½ inches tall and the postemergent applications of bentazon were made.

Bentazon was applied with a 1-quart CO_2 constant rate sprayer, calibrated to deliver the equivalent of 36 gallons of water per acre. At the time of the herbicide application, the wind speed was less than 5 mph and the air temperature was approximately 79° F. Within 3 hours of the herbicide application, all containers were irrigated with approximately 1 inch of water from an overhead irrigation system. The plants received a standard fertilization and maintenance program.

Weed control and phytotoxicity evaluations of the five genera of nursery crops were made periodically throughout the summer. Weed control was evaluated on a 0-100 scale, with 0 equaling no injury and 100 as complete control. Phytotoxicity was evaluated using the same 0-100 scale, with 0 representing no injury and 100 equaling complete crop kill. A completely randomized design was used for this study with four replications (three plants/replicate) of each treatment.

RESULTS AND DISCUSSION

Bentazon at all rates resulted in excellent postemergent yellow nutsedge control. Only at the ½ x (0.75 lb ai/A) rate was there any regrowth of the nutsedge following the single application of bentazon (Table 1).

At all rates of application of bentazon, excessive phytotoxicity was found on the Andorra Juniper, Red Osier Dogwood, and Royal Beauty Cotoneaster. Regel Privet and Blue Mist Spirea were both injured at the ½ x rate (0.75 lb ai/A); however, at the x rate (1.5 lb ai/A), this phytotoxicity was excessive (Table 2). The injury was characterized as a leaf burn, beginning at the apex and proceeding toward the base. Within a 2-3 week period, the leaf tissues were brown, giving a fired appearance, and were completely necrotic.

Bentazon should not be used in container-grown nursery stock due to the excessive phytotoxicity noted

TABLE 1.—Control of Yellow Nutsedge in Container-Grown Nursery Stock with Bentazon.

Treatment	Rate (lb ai/A)	Percent Nutsedge Control Days After Application 15	35
Bentazon	0.75	94*	85
Bentazon	1.5	99	94
Bentazon	3.0	99	98
Bentazon	6.0	100	100
Weedy Control		0	4
Hand Weeded Control		100	79

*Weed control values less than 75% are considered commercially unacceptable.

[1]Associate Professor of Horticulture and Agricultural Technician, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

TABLE 2.—Percent Herbicidal* Phytotoxicity to Five Genera of Container-Grown Nursery Crops Following Applications of Bentazon.

Treatment	Rate (lb ai/A)	Percent Phytotoxicity: Andorra Juniper	Red Osier Dogwood	Royal Beauty Cotoneaster	Regel Privet	Blue Mist Spirea
Bentazon	0.75	75.0†	70.0	37.5	20.0	7.5
Bentazon	1.5	92.5	100.0	65.0	37.5	17.5
Bentazon	3.0	100.0	100.0	92.5	47.5	30.0
Bentazon	6.0	100.0	100.0	100.0	75.0	32.5
Weedy Control		0.0	0.0	0.0	0.0	0.0
Hand Weeded Control		0.0	0.0	0.0	0.0	0.0

*Evaluated 35 days after application.
†Values greater than 20% are considered commercially unacceptable.

in this study. The use of bentazon shows great promise for the control of yellow nutsedge. It may be useful in field-grown nursery stock, where directed sprays can be employed, but more testing will be necessary. In addition, landscape contractors and professional grounds maintenance personnel who use bentazon for yellow nutsedge control in lawns should exercise extreme caution when spraying near established ornamentals.

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USB-3153 and Oxyfluorfen: Two New Experimental Herbicides for Container Nursery Stock

THOMAS A. FRETZ and WENDY J. SHEPPARD[1]

INTRODUCTION

Previous research by the senior author has demonstrated that weeds compete severely with nursery crops grown in containers, and losses in terms of plant size can be devastating (4). Cultivation is impossible in the container nursery and manual weeding on a large scale is becoming prohibitively expensive (6).

Numerous reports have recently been published comparing the effects of preemergent herbicides for controlling weeds in container-grown nursery stock (1, 2, 3, 5). Many researchers have noted that trifluralin (Treflan), DCPA (Dacthal), and diphenamed (Dymid or Enide) will control annual grass weeds, but are likely to give only sporadic control of broadleaf weeds. Similar results have been reported with the use of the experimental herbicide alachlor (Lasso) when used on container nursery crops (5).

With this in mind, a study was established in the spring of 1977 to evaluate two new preemergent herbicides for use on container-grown woody ornamentals This is part of a continuing effort to find a material that will give full season control over the wide spectrum of weeds which presently invade the typical container nursery.

MATERIALS AND METHODS

This study was conducted in the Department of Horticulture container nursery at The Ohio State University, Columbus, to evaluate USB-3153[2] (N^3,N^3-di-n-propyl-2,4-dinitro -6- trifluoromethyl -m- phenylene=diamine) and oxyfluorfen[3] (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) as preemergent herbicides in six container-grown nursery crops. Uniform cuttings of Royal Beauty Cotoneaster (*Cotoneaster dammeri* 'Royal Beauty'), Wilton Juniper (*Juniperus horizontalis* 'Wiltonii'), Regel Privet (*Ligustrum obtusifolium* 'Regelianum'), Common Weigela (*Weigela florida),* Blue Mist Spirea (*Caryopteris* x *clandonensis* 'Blue Mist'), and Red Osier Dogwood (*Cornus sericea*) were planted in 1-gallon plastic nursery containers on May 15, 1977. The medium used for all plants was composed of equal parts of peatmoss, sand, and milled hardwood bark.

Twenty-four hours prior to the application of the herbicides, large crabgrass (*Digitaria sanguinalis*), rough pigweed (*Amaranthus retroflexus),* and lambsquarter (*Chenopodium album*) were sown into the pots to insure a uniform weed population.

All herbicides with the exception of USB-3153-50WP formulation at a 3.0 lb ai/A rate were applied with a hand shaker to deliver the granules over a predetermined area. The USB-3153-50WP formulation was applied with a CO_2 constant rate sprayer calibrated to deliver a volume equivalent to 36 gallons of water per acre. Immediately following the herbicide applications, all containers were irrigated with 1 inch of water in order to activate the granular herbicides. The rates at which the herbicides were used were selected to include a ½, 1, 2, and 4x rates. All plants received a standard fertilization and maintenance program.

Weed control and phytotoxicity evaluations were made 35 and 70 days after the herbicide applications, using a 0-100% scale in comparison to the control treatments. The study was designed and analyzed as a completely randomized block with four replications (three plants/replicate) of each treatment.

RESULTS

The USB-3153 gave nearly perfect control of large crabgrass, rough pigweed, and lambsquarter 35 days after application at all rates when compared to the control treatments (Table 1) Only the ½x rate (1.5 lb ai/A) gave unsatisfactory control of large crabgrass 70 days after application, which might be expected. In addition, there were no differences noted in terms of the control of any of the weed species as a result of the wettable powder (WP) or granular application of USB-3153 at the 1x rate (3.0 lb ai/A) (Table 1 and Fig. 1).

Broadleaf weed control, as represented by the control of rough pigweed and lambsquarter, was satisfactory at all rates with the oxyfluorfen-2G at the three higher rates of application 70 days after application when compared to the control treatments (Table 1) Crabgrass control with oxyfluorfen was acceptable at only the 2 and 4x rates (4 0 and 8.0 lb ai/A) 35 days after application, while only the 4x rate (8 0 lb ai/A) rate was still providing satisfactory control 70 days after application (Table 1 and Fig. 1).

Neither the USB-3153 or oxyfluorfen treatments caused any significant quantity of plant phytotoxicity to the six plant species evaluated in this study. In-

[1]Associate Professor and Agricultural Technician, Dept of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center

[2]Trade name—GOAL

[3]Trade name—RYDEX

TABLE 1.—Control of Large Crabgrass, Rough Pigweed, and Lambsquarter in Nursery Containers.

Treatment		Percent Weed Control					
		Crabgrass		Pigweed		Lambsquarter	
	Rate	Days After Treatment					
Herbicide	(lb ai/A)	35	70	35	70	35	70
USB-3153-2G	1.5	82*	71	95	98	96	100
USB-3153-2G	3.0	95	93	100	100	100	100
USB-3153-2G	6.0	99	100	100	100	100	100
USB-3153-2G	12.0	100	100	100	100	100	100
USB-3153-50WP	3.0	100	99	100	100	100	100
Oxyfluorfen-2G	1.0	52	27	78	72	60	76
Oxyfluorfen-2G	2.0	61	37	92	94	78	89
Oxyfluorfen-2G	4.0	78	51	98	96	87	90
Oxyfluorfen-2G	8.0	93	78	99	98	99	98
Hand weeded control	—	37	64	39	58	38	70
Weedy control	—	36	5	36	33	36	33

*Weed control values less than 75% are considered commercially unacceptable.

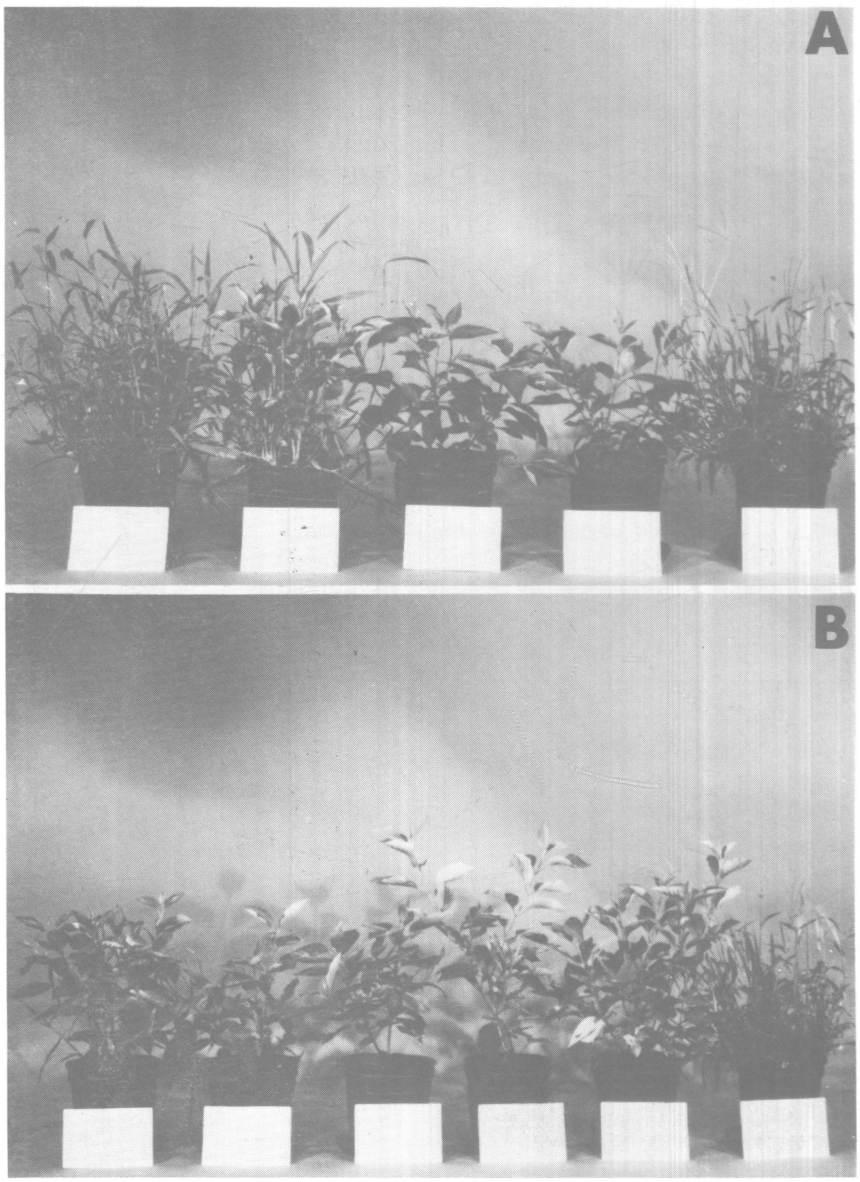

FIG. 1.—Weed control in Red Osier Dogwood. (A) Left to right: oxyfluorfen at 1.0, 2.0, 4.0, 8.0 lb ai/A and weedy control. (B) Left to right: USB-3153-2G at 1.5, 3.0, 6.0, 12.0 lb ai/A, USB-3153-50WP at 3.0 lb ai/A, and weedy control.

TABLE 2.—Percent Herbicidal Phytotoxicity* to Six Genera of Container-grown Nursery Crops 70 Days After Application.

Treatment		Percent Phytotoxicity					
Herbicide and Formulation	Rate (lb ai/A)	Royal Beauty Cotoneaster	Wilton Juniper	Regel Privet	Weigela	Blue Mist Spirea	Red Osier Dogwood
USB-3153 2G	1.5	8 0†	0.0	0 0	0.0	0.0	0.0
USB-3153 2G	3.0	10.0	0.0	0.0	0.0	0.0	0.0
USB-3153 2G	6.0	0.0	0.0	0.0	8.0	0.0	0.0
USB-3153 2G	12.0	0.0	0.0	15.0	15.0	0.0	0.0
USB-3153 50WP	3.0	0.0	0.0	0.0	0.0	5.0	0.0
Oxyfluorfen 2G	1.0	0.0	0 0	0.0	0.0	0.0	0.0
Oxyfluorfen 2G	2.0	10.0	0.0	7.5	0 0	0.0	0.0
Oxyfluorfen 2G	4.0	0.0	0.0	0.0	0.0	0 0	3.0
Oxyfluorfen 2G	8.0	7.5	0 0	0.0	0.0	0.0	8.0
Hand weeded control	—	0.0	0.0	17.5	0.0	0.0	0.0
Weedy control	—	0.0	0.0	0.0	0.0	0.0	0.0

*Evaluated 35 days after application.
†Values greater than 20% are considered commercially unaccepable.

terestingly, even the 4x rates of both herbicides exhibited exceedingly little phytotoxicity, indicating the relative safety of both of these herbicides (Table 2).

This study indicates that USB-3153 has potential for providing full-season, wide spectrum broadleaf and grass weed control with a great safety range in terms of plant phytotoxicity.

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Evaluation of Herbicides for Control of Yellow Nutsedge on Nursery Fields

RODNEY J. RAKER[1]

INTRODUCTION

Yellow nutsedge (*Cyperus esculentus* L.) can be a particularly troublesome weed in nursery crops. The tremendous reproductive potential of nutsedge tubers (commonly called "nuts" or "nutlets"), rhizomes, and seeds can cause a small infestation to spread rapidly to a problem of major proportions (1).

Most herbicides commonly used in the nursery to control annual weeds do not control yellow nutsedge. Continued use of such herbicides helps to create a weed competition void into which nutsedge populations can expand (1). The reproductive potential of nutsedge and the widespread use of herbicides which do not control nutsedge help to explain why severe nutsedge infestations can overtake nursery fields seemingly overnight.

Field cultivation and hoeing alone do not offer the ultimate solution to a yellow nutsedge infestation problem. Consequently, two studies were initiated to evaluate both preemergent and postemergent herbicides for control of yellow nutsedge.

MATERIALS AND METHODS

The first study was conducted in a fallow field in Perry, Ohio. The entire 3,900 square foot test area had a sandy loam soil type and a well-established population of 4-7 inch tall nutsedge weeds. Four preemergent and two postemergent herbicides at two rates each were applied to 100 square foot plots. A completely randomized design was used with three replications (100 square foot plot/replicate) of each treatment.

All treatments were applied on July 14, 1976, with a 2-gallon pump sprayer and a quantity of water equivalent to 40 gallons per acre. The lower treatment rate for each herbicide tested represents the approximate manufacturer's recommended dosage. The actual rates of application are listed in Table 1.

In accordance with the manufacturer's recommendations, the preemergent herbicides EPTC (Eptam), Napropamide (Devrinol), and Napropamide-Simazine were incorporated immediately after application to a depth of 6 inches with a tractor driven rototiller. The plots to which the preemergent herbicide Alachlor (Lasso) was applied were rototilled first and then treated. Plots treated with Glyphosate (Roundup), Bentazon (Basagran), and the control were not mechanically incorporated.

Nutsedge control for both preemergent and postemergent herbicide treatments was evaluated on Sept. 1, 1976. Control was measured as a percent with values less than 80% being considered commercially unacceptable (Table 1).

A second study was initiated in a commercial nursery in Madison, Ohio, on July 26, 1977, to more fully evaluate Bentazon. Two rates of Bentazon (2 and 3 lb ai/A) were applied as described in the first study to 100 square foot plots in which were growing 8-inch *Taxus media* 'Brownii' liners (planted in May 1977) and a substantial population of 6-8 inch yellow nutsedge plants. The herbicides were sprayed on the *Taxus* liners as well as the nutsedge plants. The treatments were again arranged in a completely randomized design with three replicates of each treatment. The study was evaluated on August 5, 1977, with nutsedge control expressed on a percentage basis.

RESULTS AND DISCUSSION

Study 1

With the exception of Alachlor at the 6 lb ai/A rate, all of the preemergent herbicides tested substantially reduced nutsedge population density, with EPTC, Napropamide, and Napropamide-Simazine providing virtually complete nutsedge control at the time of evaluation. Alachlor at the 6 lb ai/A rate, while reducing nutsedge density, did not provide commercially acceptable control.

TABLE 1.—Control of Yellow Nutsedge in a Fallow Field.

Herbicides	Trade Name and Formulation	Rate (lb ai/A)	Nutsedge Control* (%)
EPTC	Eptam-7 EC	8.9	99
		11.9	100
Alachlor	Lasso-4 EC	6.0	72
		8.0	98
Napropamide	Devrinol-50 WP	6.0	100
		8.0	93
Napropamide-Simazine	Devrinol-Simazine 40-10 WP	6 + 1.5	99
		8 + 2.0	100
Glyphosate	Roundup-3 EC	3.0	17
		6.0	33
Bentazon	Basagran-4 EC	2.0	100
		3.0	99
Non-weeded control			23

*Values less than 80% are considered commercially unacceptable.

[1]County Extension Agent, Horticulture, Ohio Cooperative Extension Service.

The study indicates that control of yellow nutsedge with preemergent herbicides can be accomplished in mid-summer when nutsedge plants are rapidly growing if the nutsedge plants are thoroughly rototilled at the time of herbicide application. Thorough cultivation provided by a tractor-driven rototiller apparently disrupts established nutsedge plants long enough to allow preemergent herbicides to penetrate the soil and prevent re-infestation. The extent to which rototilling alone (without the application of preemergent herbicides) may suppress nutsedge reinfestation cannot be determined since a rototilled, untreated control plot was omitted from the study.

Of the preemergent herbicides tested, EPTC is the only one currently labeled for use on nursery crops. When EPTC is thoroughly incorporated into the soil immediately after application, good control of nutsedge in the nursery can be expected. The control may be only temporary (less than season-long), however, since agronomists at The Ohio State University report that EPTC and Alachlor cause nutsedge nutlets to go dormant, but do not kill them. After the residual effects of these herbicides decrease, the nutlets may break dormancy and produce new nutsedge shoots (1, 2). The length of the control period of Napropamide and Napropamide-Simazine and their actual effect on nutsedge tubers have not yet been determined.

Control of yellow nutsedge with the postemergent herbicide Bentazon was excellent for both the 2 and 3 lb ai/A rates. Glyphosate at the 3 and 6 lb ai/A rates severely burned and stunted the nutsedge plants but did not kill them. Previous reports have noted that Bentazon does kill the tubers (1), as was observed in this study.

Study 2

Outstanding control of yellow nutsedge provided by Bentazon in Study 1 warranted a succeeding study to evaluate the effects of Bentazon on nutsedge in a crop situation. Bentazon at the 2 lb ai/A rate again provided excellent yellow nutsedge control which was commercially acceptable, while the 3 lb ai/A treatment provided virtually complete control.

The young *Taxus* liners were closely inspected and no phytotoxicity or stunting of growth was noted

TABLE 2.—Control of Yellow Nutsedge in a Field of Taxus **Liners.**

Herbicides	Trade Name and Formulation	Rate (lb ai/A)	Nutsedge Control* (%)
Bentazon	Basagran 4 EC	2.0	90
Bentazon	Basagran 4 EC	3.0	98
Non-weeded control			17

*Values less than 80% are commercially unacceptable.

both at the time of weed control evaluation and 60 days after treatment.

SUMMARY

Yellow nutsedge can be controlled using the preemergent herbicides EPTC (Eptam), Napropamide (Devrinol), and Napropamide-Simazine even after nutsedge plants are actively growing, provided the herbicides and the nutsedge plants are thoroughly incorporated into the soil by rototilling. EPTC is labeled for certain nursery crops and will provide good nutsedge control. The limitations of EPTC include the necessity of incorporation and the possibility that control may be less than season-long.

Control of yellow nutsedge with the postemergent herbicide Bentazon (Basagran) was excellent. Bentazon is apparently non-phytotoxic to *Taxus* plants and provides an extended period of nutsedge control. It is not, however, currently labeled for use on nursery stock.

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Phytotoxicity of Glyphosate on Landscape Plants

ELTON M. SMITH and SHARON A. TREASTER[1]

INTRODUCTION

Glyphosate, a relatively new herbicide, is one of the most effective in the control of perennial weeds. One major advantage for its use is the lack of residue in the soil which is highly desirable near landscape plants. Currently, glyphosate is labeled for weed control in fields prior to planting certain agronomic crops such as corn and soybeans, under non-bearing deciduous tree fruit crops, and in non-crop areas. Hopefully, it will be approved soon by the Environmental Protection Agency (EPA) for use in nursery and landscape crops.

If this herbicide is registered for use on landscape plants, it's likely to first be approved as a preplant treatment. Secondly, it will be requested for use in established plantings of trees. This use has been investigated quite thoroughly during 1975 and 1976 by the author (14) and others (6, 7, 8, 10, 13) and will not be the topic of this report. Lastly, and the least likely area of approval due to the high probability of plant injury, would be use as a spot treatment to control perennial weeds in nursery or landscape plantings. These two studies were undertaken to more clearly define its application in the landscape area.

The first study was undertaken to determine whether glyphosate could be used safely as a preplant treatment to control existing weeds prior to planting landscape plants. The specific objective was to evaluate for phytotoxicity on several popular ornamentals from ground covers to shade trees. Although only a limited number of studies have been conducted with glyphosate as a preplant treatment, the following plants have not been injured following planting into a treated area: euonymus (5), juniper (4, 5), taxus (4), and white pine (5). Injury symptoms have not been reported on landscape plants following a preplant treatment.

A second area of investigation was initiated to evaluate the susceptibility of a wide number of ornamentals to intentional foliage contact with glyphosate. Glyphosate is a systemic herbicide which affects most green plant parts; however, data from several studies indicate that a number of landscape plants may be tolerant. Similar studies have revealed a list of susceptible plants. Among the landscape plants reported to be tolerant to contact with glyphosate are the following evergreens: arborvitae (11), Douglas fir (6), English ivy (9), false cypress (11), Japanese holly (7), juniper (7, 8, 9, 11, 12), pachysandra (9), mugho (6) and dormant white pine (6), Norway spruce (7), and Hicks yew (7).

Found to be injured to some degree were *Azalea hinodigiri* (6), Rock Spray Cotoneaster (12), Toringo Crabapple (8), Euonymus Sarcoxie (4) and Emerald Cushion (6), forsythia (6, 7), Douglas fir (2), sweet gum (7), and Canadian hemlock (9). Also included in this list are Nikko Blue Hydrangea (4), Hypericum Hidcote (6), Kalmia (1), Japanese maple (7), *Mahonia aquifolium* (6), pieris (6), pine (2), privet (7), *Rosa alba* (6), rhododendron (1), *Spiraea nipponica* (6), and taxus (6).

STUDY I—GLYPHOSATE INJURY AS A PREPLANT TREATMENT

Soil in The Ohio State University nursery was sprayed with glyphosate at 8.0 lb ai/A on May 20, 1977. Within 3 hours from the time the herbicide had dried on the soil, 11 species of ornamentals were planted in the treated area. Under normal situations, planting would have been delayed for 10-14 days from a 1.5 lb ai/A rate to allow for weed control. However, the waiting time was avoided in this study to increase the chance of glyphosate uptake.

To achieve a cross section of landscape plants, the following species and sizes were included: *Acer rubrum* 'Red Sunset' — 5-6', *Forsythia intermedia* 'Spectabilis' — 1-1½', *Fraxinus americana* 'Autumn Purple' — 7-8', *Hedera helix* — 3" pots, *Juniperus horizontalis* 'Plumosa Compacta' — 9-12", *Malus* 'Radiant' —6-7', *Pachysandra terminalis* — 3" pots, *Pinus strobus* — 6-8" seedlings, *Quercus palustris* — 3', *Taxus media* 'Thayeri' — 9-12", and *Weigela florida* 'Newport Red' — 1-1½'.

Two to three plants per treatment were planted, with each treatment replicated three times in a randomized block pattern.

Evaluations for phytotoxicity were conducted at 30, 60, and 90-day intervals.

There was no injury from the herbicide on any plants at any of the three evaluation periods. Since the application rate was four to five times higher than recommended to control most perennial weeds and no injury has previously been reported on landscape plants when used as a preplant, it appears glyphosate will have a significant degree of safety when used preplant on ornamentals.

[1]Professor and Agricultural Technician, Dept. of Horticulture, The Ohio State University and Ohio Agricultural Research and Development Center.

STUDY II—GLYPHOSATE INJURY AS A CONTACT TREATMENT

This study was initiated to ascertain which landscape plants will be more tolerant and which will most likely be susceptible to glyphosate if it becomes registered for use in nursery and landscape plantings. Several researchers have evaluated glyphosate for spot treatment of perennial weeds in existing ornamental plantings and have indicated plant tolerances and susceptibility (1, 2, 4, 6-9, 11, 12).

TABLE 1.—Phytotoxicity from Directed Sprays of Glyphosate at 3.0 lb ai/A on the Foliage of Woody Ornamentals 1 Month Following Treatment on August 17, 1977.

Plants Treated	Phytotoxicity: Plants Injured	Phytotoxicity: Plants Not Injured
Acer ginnala	X	
Acer negundo	X	
Acer platanoides	X	
Acer saccharum	X	
Ajuga reptans		X
Berberis thunbergi	X	
Cornus sanguinea	X	
Crataegus phaenopyrum	X	
Cotoneaster divaricata	X	
Elaeagnus augistifolia	X	
Euonymus alatus		X
Euonymus fortunei 'Coloratus'	X	
Euonymus fortunei 'Manhattan'	X	
Forsythia intermedia 'Spectabilis'	X	
Fraxinus pennsylvanica lanceolata	X	
Ginkgo biloba		X
Gleditsia 'Shademaster'	X	
Hamamelis vernalis	X	
Hedera helix	X	
Hibiscus syriacus	X	
Ilex crenata 'Hetz'	X	
Juniperus c. 'Pfitzeriana'	X	
Ligustrum obtusifolium regelianum	X	
Lonicera fragrantissima	X	
Lonicera japonica 'Halliana'	X	
Malus 'Snowdrift'	X	
Morus alba	X	
Myrica pensylvanica	X	
Pachysandra terminalis		X
Picea abies		X
Picea pungens 'Glauca'		X
Pinus nigra		X
Pinus sylvestris		X
Pinus thunbergi		X
Pyracantha coccinea 'Lalandei'	X	
Quercus imbricaria	X	
Quercus robur	X	
Rhododendron 'Mollis'	X	
Syringa vulgaris	X	
Taxus media 'Browni'		X
Thuja occidentalis 'Techny'	X	
Tilia euchlora		X
Ulmus parviflora	X	
Viburnum lantana	X	
Vinca minor		X

In a preliminary study to determine tolerances, two to three branches of 45 species and cultivars of woody ornamentals were sprayed with glyphosate at 3.0 lb ai/A. The herbicide was applied on August 17, 1977, with a compressed air, 3-gallon, pump-type sprayer without additional spreader sticker. The August treatment date was selected to provide maximum summer maturity of the ornamentals. Plants were evaluated Sept. 17, 1977.

The results reveal that approximately 75% of the plants were injured to some degree, from slight foliage discoloration to complete death of the treated branches (Table 1). Interestingly, translocation of the herbicide was not extensive and damage was basically confined to the sprayed plant parts. These results agree with findings from previous studies that have indicated injury on cotoneaster, crabapple, euonymus, forsythia, maple, privet, and rhododendrons.

The plants that were not injured are primarily needle-type evergreens and ground covers. Pine, spruce, taxus, arborvitae, and pachysandra have all previously been suggested as tolerant of glyphosate. However, this only implies potential resistance and more research is needed.

SUMMARY

In summary, glyphosate (8.0 lb ai/A) application as a preplant treatment to control weeds in a nonplanted area will not result in injury to a number of landscape plants when planted in those treated soils. Secondly, glyphosate (3.0 lb ai/A) used to control weeds on a spot treatment basis in ornamental plants will injure deciduous trees and shrubs if the foliage is contacted by the spray. Certain plants such as narrow-leaved evergreens and some ground covers appear to be tolerant. Further evaluations are suggested in this area to more closely define rates, timing, and more extensive species response.

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